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WATER & SEWAGE WORKS

REFERENCE *and* DATA NUMBER

JUNE 15, 1956

Water & Sewage Works Presents Its 1956 R & D Number

For the 23rd time
Water & Sewage Works magazine is
publishing an annual reference and data section.

This 1956 Number,
issued as a separate volume, continues
the traditional intent of the publisher and the editors
to produce a useful reference and information work.

The Reference and Data Numbers
are essentially handbooks on the management, maintenance,
operation, and engineering fundamentals in the field of
water and sewage works practices. These "handbooks" are
divided into ten sections and each year the "handbook" is
revised and updated with new articles and reference material
published during the preceding year.

Fundamental Articles
of lasting interest and usefulness are reprinted
in the Reference and Data Numbers at intervals of two
to three years. This practice is followed to provide new
subscribers with basic material for their libraries.
Therefore, it is suggested that subscribers retain the last
three Reference and Data Numbers in order to have a
complete "handbook" on the subject of water and sewage works.

Subscribers
to water & Sewage Works receive the Reference and
Data Numbers without extra charge.

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reference and data number

WATER & SEWAGE WORKS

reference and data number

*** JUNE 15, 1956**

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WATER & SEWAGE WORKS

reference and data number

* JUNE 15, 1956

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ACID SULFURIC AND HYDROCHLORIC
Consolidated Chemical Industries
Diamond Alkali Co.
Frontier Chemical Co.
General Chemical Div.
International Minerals & Chemical Corp.
Olin Mathieson Chemical Corp.
Pennsylvania Salt Mfg. Co.
Pennsalt of Washington
Tennessee Corp.
U. S. Rubber Co.

ACTIVATED ALUM
General Chemical Div.
Olin Mathieson Chemical Corp.
Pennsylvania Salt Mfg. Co.

ACTIVATED CARBON
Fine Organics, Inc.
Graver Water Conditioning Co.
Infilco, Inc.
Lakeside Engr. Corp.
Stuart Corp.
Permutit Co.
Pittsburgh Coke & Chemical Co.
West Virginia Pulp and Paper Co.

ACTIVATED SILICA GENERATORS
Omega Machine Co.
Wallace & Tiernan, Inc.

AERATION APPARATUS
American Water Softener Co., Inc.
American Well Works
Chicago Pump Co.
Dorr-Oliver, Inc.
General Filter Co.
Graver Water Conditioning Co.
Infilco, Inc.
Jeffrey Mfg. Co.
Lakeside Engr. Corp.
Pacific Flush Tank Co.
Permutit Co.
Smith & Loveless, Inc.
Walker Process Equip., Inc.
Yeomans Bros. Co.

AGITATORS
American Water Softener Co., Inc.
Dorr-Oliver, Inc.
General Filter Co.
Graver Water Conditioning Co.
Hardinge Co., Inc.
Infilco, Inc.
Jeffrey Mfg. Co.
F. B. Leopold Co., Inc.
Link-Belt Co.
Philadelphia Gear Works, Inc.
Stuart Corp.
Walker Process Equip., Inc.
Western Machinery Co.
Worthington Corp.

AIR BLOWERS
(Sees Blowers, Air)

AIR COMPRESSORS
(See Compressors, Air)

AIR RELIEF VALVES
Darling Valve & Mfg. Co.
Eddy Value Co.
Ludlow Value Mfg. Co.
Multiplex Mfg. Co.
Rensselaer Valve Div.
Simplex Valve & Meter Co.

ALTERNATORS, ELECTRIC
Allis-Chalmers Mfg. Co.
Electric Machinery Mfg. Co.
Fairbanks Morse & Co.
General Electric Co.
Healy-Ruff Co.
Smith & Loveless, Inc.

AMMONIA, ANHYDROUS AND AQUA
Columbia-Southern Chemical Corp.
General Chemical Div.
John Wiley Jones, Co.
Olin Mathieson Chemical Corp.
Pennsylvania Salt Mfg. Co.
Pennsalt of Washington

AMMONIATORS
American Water Softener Co., Inc.
Everson Mfg. Co.
Fischer & Porter Co.
Omega Machine Co.
Proportioneers, Inc.
Wallace & Tiernan Inc.

ANTHRAFILT
Anthracite Equipment Corp.
Graver Water Conditioning Co.
Infilco, Inc.
Stuart Corp.
Walker Process Equip., Inc.

ARRESTERS, FLAME
Pacific Flush Tank Co.

ASH AND COAL HANDLING MACHINERY
Beaumont Birch Co.
Bucyrus-Erie
Chain Belt Co.
Jeffrey Mfg. Co.
Link-Belt Co.
Oliver Corp.
Stuart Corp.

BAR SCREENS
(See Screens, Sewage)

BINS, STORAGE
Beaumont Birch Co.
Bethlehem Steel Co.
Graver Water Conditioning Co.
Jeffrey Mfg. Co.
Natco Corp.
Nooter Corp.
Pittsburgh—Des Moines Steel Co.
Preload Co., Inc.

BITUMINOUS COATINGS AND LININGS
Alco Products, Inc.
The Carborundum Co.
Chemical Fire & Rust Proofing Co.
Colonial Plastics Mfg. Co.
Hercules Powder Co.
Johns-Manville
Koppers Co., Inc.
J. W. Mortell Co.
Philadelphia Quartz Co.
Pittsburgh Coke & Chemical Co.
Presstite-Keystone Engr. Products Co.

BLEACHING POWDER
(See Calcium Hypochlorite)

BLOWERS AIR, GAS
Allis-Chalmers Mfg. Co.
Chicago Pump Co.
De Laval Steam Turbine Co.
Homelite Div.
Roots-Connersville Blower Div.

BOILER BREECHINGS
(See Breechings, Steel)

BOILER FEEDWATER TREATMENT AND EQUIPMENT
Alco Products Inc.
Allis-Chalmers Mfg. Co.
American Water Softener Co., Inc.
Builders-Providence, Inc.
Chemical Equipment Co.
Fischer & Porter Co.
General Filter Co.
Graver Water Conditioning Co.
Infilco, Inc.
Lakeside Engr. Corp.
Permutit Co.
Phipps & Bird, Inc.
Proportioneers Inc.
Roberts Filter Mfg. Co.
Wallace & Tiernan Inc.

BOILERS, GAS
Combustion Engineering Inc.

BOXES, VALVE AND METER
(See Valve Boxes; Meter Boxes)

BRASS GOODS
W. S. Darley & Co.
Grinnell Company
Mueller Co.

BREECHING, STEEL
Bethlehem Steel Co.
Hammond Iron Works
Nooter Corp.
Pittsburgh-Des Moines Steel Co.

BUCKET ELEVATORS
(See Conveyors and Conveying Equip.)

BUFFER SOLUTIONS AND TABLETS
Phipps & Bird, Inc.
W. A. Taylor & Co.

BUTTERFLY VALVES
(See Valves, Butterfly)

CABLE, ELECTRIC
General Electric Co.
U. S. Rubber Co.

CABLE, FLEXIBLE
Bailey Meter Co.
Builders-Providence Inc.

CALCIUM HYPOCHLORITE
Columbia Southern Chemical Div.
John Wiley Jones Co.
Olin Mathieson Chemical Corp.
Pennsylvania Salt Mfg. Co.
Pennsalt of Washington
Proportioneers, Inc.

CARBON-ACTIVATED
(See Activated Carbon)

CARBONATORS (Recarbonation)
American Well Works
General Filter Co.
Graver Water Conditioning Co.
Infilco, Inc.
Lakeside Engr. Corp.
F. B. Leopold Co., Inc.
Permutit Co.
Smith & Loveless, Inc.
Walker Process Equip., Inc.

CASTINGS, IRON, STEEL, ALLOY STEEL, ETC.
ACF Industries, Inc.
Bethlehem Steel Co.
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
Chain Belt Co.
Filer & Stowell Co.
Hardinge Co., Inc.
Jeffrey Mfg. Co.
Link-Belt Co.
United States Pipe & Foundry Co.

CATHODIC PROTECTIVE SYSTEMS
Chemical Fire & Rust Proofing Corp.
Electro Rust-Proofing Corp.
Smith & Loveless, Inc.

CAULKING MACHINES AND TOOLS
Mueller Co.
Joseph G. Pollard Co., Inc.

CEMENT ASBESTOS PIPE
Johns-Manville
Keasbey & Mattison Co.

CEMENT GUN
Cement Gun Co.

CEMENT LINING OF PIPE
Cast Iron Pipe Research Assn.
Centriline Corp.
Chemical Fire & Rust Proofing Corp.
James B. Clow & Sons

CEMENTS, ACID PROOF AND ALKALI
Johns-Manville
J. W. Mortell Co.
Pennsylvania Salt Mfg. Co.

CEMENTS, REFRACTORY
The Carborundum Co.
Johns-Manville

CEMENTS, SEWER PIPE
Hydraulic Development Co.
Johns-Manville
Presstite-Keystone Eng. Products Co.
Price Bros. Co.

CEMENTS, WATER MAINS
Hydraulic Development Co.
Price Bros. Co.

CHAINS (Elevating, Conveying and Power Transmission)
Beaumont Birch Co.
Chain Belt Co.
Hydraulic Development Co.
Jeffrey Mfg. Co.
Link-Belt Co.

CHEMICAL CONTROL EQUIP.
(See Laboratory Apparatus and Reagents)

CHEMICAL, CONVEYING EQUIPMENT
Beaumont Birch Co.
Chain Belt Co.
Colonial Plastics Mfg. Co.
Infilco, Inc.
Jeffrey Mfg. Co.
Link-Belt Co.
U. S. Rubber Co.

CHEMICAL FEEDING AND PROPORTIONING EQUIP.
American Water Softener Co., Inc.
Bailey Meter Co.
Beaumont Birch Co.
Builders-Providence, Inc.
Chemical Equipment Co.
Control Corp.
Everson Mfg. Co.
Fischer & Porter Co.
General Filter Co.
Graver Water Conditioning Co.
Infilco Inc.
Jeffrey Mfg. Co.
Komline-Sanderson Engineering Corp.
Lakeside Engr. Corp.
F. B. Leopold Co., Inc.
Modern Swimming Pool Co., Inc.
Omega Machine Co.
Permutit Co.
Proportioneers, Inc.
Taller & Cooper, Inc.
Wallace & Tiernan, Inc.

CHLORINATORS
American Water Softener Co., Inc.
Builders-Providence, Inc.
Chemical Equipment Co.
Everson Mfg. Co.
Fischer & Porter Co.
Modern Swimming Pool Co., Inc.
Olin Mathieson Chemical Corp.
Proportioneers, Inc.
Wallace & Tiernan, Inc.

CHLORINE CONTROL EQUIP.
(See Residual Chlorine Control)

CHLORINE DIOXIDE
(See Sodium Chlorite)

CHLORINE, LIQUID
Columbia-Southern Chemical Corp.
Diamond Alkali Co.
Frontier Chemical Co.
John Wiley Jones Co.
International Minerals & Chemical Corp.
Modern Swimming Pool Co., Inc.
Olin Mathieson Chemical Corp.
Niagara Alkali Co.
Pennsylvania Salt Mfg. Co.
Pennsalt of Washington

CLAMPS AND SLEEVES, PIPE
James B. Clow & Sons
W. S. Darley & Co.
Dresser Mfg. Div.
Mueller Co.
U. S. Rubber Co.

CLAMPS, BELL JOINT
James B. Clow & Sons
W. S. Darley & Co.
Dresser Mfg. Div.
M. B. Skinner Co.

CLAMPS, PIPE REPAIR
James B. Clow & Sons
W. S. Darley & Co.
Dresser Mfg. Div.
Mueller Co.
M. B. Skinner Co.

CLARIFIERS, SEWAGE AND WATER
American Water Softener Co., Inc.
American Well Works
Chain Belt Co.
Chicago Pump Co.
Dorr-Oliver, Inc.
General Filter Co.
Graver Water Conditioning Co.
Hardinge Co., Inc.
Infilco, Inc.
Jeffrey Mfg. Co.
Lakeside Engr. Corp.
Link-Belt Co.
Permutit Co.
Walker Process Equip., Inc.
Yeomans Bros. Co.

CLAY PIPE
(See Vitrified Clay Pipe and Products)

CLEANING WATER MAINS
Flexible Pipe Cleaning Co.
Flexible Inc.
National Power Rodding Corp.
National Water Main Cleaning Co.
Phelps Dodge Refining Corp.

COAGULATING AIDS
The Carborundum Co.
Chemical Fire & Rust Proofing Corp.
Dorr-Oliver, Inc.
Infilco, Inc.
Link-Belt Co.
Modern Swimming Pool Co., Inc.
Pennsylvania Salt Mfg. Co.
Philadelphia Quartz Co.
Wallace & Tiernan, Inc.

COAL AND ASH HANDLING MACHINERY
(See Ash and Coal Handling Machinery)

COATINGS, ACID AND ALKALI-PROOF
Amercoat Corp.
Chemical Fire & Rust Proofing Corp.
Colonial Plastics Mfg. Co.
Hamilton Kent Mfg. Co.
Hercules Powder Co., Inc.
Johns-Manville
Koppers Co., Inc.
J. W. Mortell Co.
Pennsylvania Salt Mfg. Co.
Pittsburgh Coke & Chemical Co.
Smith & Loveless, Inc.
U. S. Rubber Co.

COATINGS AND LININGS
(See Bituminous Coatings and Linings)

COCKS (Curb, Meter, Corp. etc.)
Crane Co.
Dezurik Shower Co.
Homestead Valve Mfg. Co.
Mueller Co.

COLLECTORS (Sludge)
(See Sludge Collectors)

COLORIMETERS
(See Photoelectric Colorimeters)

COMBUSTION INDICATORS AND RECORDERS
Bailey Meter Co.
Arnold O. Beckman, Inc.
Control Corp.
Fischer & Porter Co.
Minneapolis-Honeywell Regulator Co.
Permutit Co.
Taller & Cooper, Inc.

COMMINUTING DEVICES
American Well Works
Chain Belt Co.
Chicago Pump Co.
Infilco, Inc.
Worthington Corp.

COMPARATORS, COLOR
Phipps & Bird, Inc.
W. A. Taylor & Co.
Wallace & Tiernan Inc.

COMPOUNDS, JOINT
(See Jointing Compounds and Materials)

COMPRESSORS, AIR
Allis-Chalmers Mfg. Co.
De Laval Steam Turbine Co.
Le Roi Div.,
Multiplex Mfg. Co.
Schramm Inc.
Worthington Corp.
Yeomans Bros. Co.

CONCRETE BREAKERS
Le Roi Div.
Schramm, Inc.
Worthington Corp.

CONCRETE HARDENER
Philadelphia Quartz Co.
Standard Dry Wall Products, Inc.

CONCRETE MIXER
Chain Belt Co.
Worthington Corp.

CONCRETE PIPE (Water and Sewage)
American Concrete Pipe Assn.
American Concrete Pressure Pipe Assn.
American Vitrified Products Co.
Lock Joint Pipe Co.
Portland Cement Assn.
Price Bros. Co.

CONDENSERS (Steam)
Alco Products, Inc.
Allis-Chalmers Mfg. Co.
Economy Pumps, Inc.
Worthington Corp.

CONTRACTORS (Water and Sewage Work)
Layne & Bowler, Inc.
F. B. Leopold Co., Inc.
Preload Co., Inc.
Ranney Method Water Supplies, Inc.

CONTROLLERS FLOW, LEVEL, PRESSURE, TEMPERATURE
Bailey Meter Co.
Ernest Bernard Elec. Co.
Builders-Providence, Inc.
Control Corp.
Fischer & Porter Co.
Foxboro Co.
General Electric Co.
General Filter Co.
Healy-Ruff Co.
Infilco, Inc.
Leupold & Stevens Instruments, Inc.
Minneapolis-Honeywell Regulator Co.
Simplex Valve & Meter Co.
Smith & Loveless, Inc.

CONVEYORS AND CONVEYING EQUIPMENT
American Well Works
Beaumont Birch Co.
Builders-Providence, Inc.
Chain Belt Co.
Gruendler Crusher & Pulverizer Co.
Jeffrey Mfg. Co.
Link-Belt Co.
Morse Boulger Destructor Co.
Oliver Corp.
Omega Machine Co.
Philadelphia Gear Works, Inc.
Stuart Corp.
Walker Process Equip., Inc.

COPPER SULFATE
Phelps Dodge Refining Corp.
Tennessee Corp.

COPPER TUBING AND RED BRASS PIPE
Mueller Co.

CORPORATION AND CURB COCKS
(See Cocks-Corp., Curb & Meter)

CORROSION SUPPRESSION
Amercoat Corp.
Calgon, Inc.
Chemical Fire & Rust Proofing Corp.
Electro Rust-Proofing Corp.
Koppers Co., Inc.
J. W. Mortell Co.
Mueller Co.
Pittsburgh Coke & Chemical Co.

COUPLINGS AND CONNECTIONS, PIPE
A. M. Byers Co.
James B. Clow & Sons
Crane Co.
Dresser Mfg. Div.
Johns-Manville
Mueller Co.

COUPLINGS, FLEXIBLE
Chain Belt Co.
James B. Clow & Sons
De Laval Steam Turbine Co.
Hamilton Kent Mfg. Co.
Jeffrey Mfg. Co.
Johns-Manville
Link-Belt Co.
U. S. Rubber Co.

CULVERT PIPE
(See Pipe, Culvert)

CURB, BOXES
Alabama Pipe Co.
James B. Clow & Sons
Filtration Equipment Corp.
Mueller Co.

DECHLORINATING EQUIPMENT AND CHEMICALS
American Water Softener Co., Inc.
Chemical Equipment Co.
General Chemical Div.
Graver Water Conditioning Co.
Infilco, Inc.
Omega Machine Co.
Permutit Co.
Proportioneers, Inc.
Tennessee Corp.
Wallace & Tiernan, Inc.

DE-MINERALIZATION EQUIPMENT (Water)
Allis-Chalmers Mfg. Co.
American Water Softener Co., Inc.
Chemical Equipment Co.
Dorr-Oliver, Inc.
General Filter Co.
Graver Water Conditioning Co.
Infilco, Inc.
Lakeside Engr. Corp.
Layne & Bowler, Inc.
Permutit Co.
Phipps & Bird, Inc.

DEODORIZING (Service, Equipment, Chemicals, etc.)
Airkem, Inc.
American Water Softener Co., Inc.
Chemical Equipment Co.
Columbia-Southern Chemical Corp.
Fine Organics, Inc.
Lakeside Engr. Corp.
Olin Mathieson Chemical Corp.
Permutit Co.
Reliance Chemicals Corp.
Wallace & Tiernan, Inc.
West Virginia Pulp & Paper Co

DIATOMITE FILTER SEPTUMS
American Water Softener Co., Inc.
Carborundum Co.
Dorr-Oliver, Inc.
General Filter Co.
Graver Water Conditioning Co.
Infilco, Inc.
Edward E. Johnson, Inc.
Lakeside Engr. Corp.
Permutit Co.
Proportioneers, Inc.

DIESEL ENGINES
(See Engines, Diesel)

DIFFUSERS—PLATES, TUBES AND FITTINGS
American Well Works
The Carborundum Co.
Chicago Pump Co.
Filtros, Inc.
Infilco, Inc.
Link-Belt Co.
Pacific Flush Tank Co.
Walker Process Equip., Inc.

DIGESTER EQUIPMENT (Sludge)
American Well Works
Chicago Pump Co.
Dorr-Oliver, Inc.
Hardinge Co., Inc.
Infilco, Inc.
Jeffrey Mfg. Co.
Lakeside Engr. Corp.
Pacific Flush Tank Co.
Walker Process Equip., Inc.
Yeomans Bros. Co.

DISTRIBUTORS (Sewage Filter)
American Well Works
Dorr-Oliver, Inc.
Infilco, Inc.
Lakeside Engr. Corp.
Pacific Flush Tank Co.
Smith & Loveless, Inc.
Walker Process Equip., Inc.
Yeomans Bros. Co.

DRAINS, GUTTER, FLOOR
Chemical Equipment Co.
James B. Clow & Sons
Modern Swimming Pool Co., Inc.

DRILLING AND BORING EQUIPMENT
Bucyrus-Erie
Layne & Bowler, Inc.
Mueller Co.
Schramm Inc.
Worthington Corp.

DRIVES, CHAIN
(See Chains)

DRIVES, RIGHT ANGLE GEAR
De Laval Steam Turbine Co.
Link-Belt Co.
Payne Dean & Co.
Philadelphia Gear Works Inc.
U. S. Electrical Motors, Inc.

DRIVES, V-BELT
Allis-Chalmers Mfg. Co.
Link-Belt Co.
Worthington Corp.

DRYING SYSTEMS (Sludge)
Allis-Chalmers Mfg. Co.
Beaumont Birch Co.

Combustion Engineering, Inc.
Hardinge Co., Inc.
Komline-Sanderson Engineering Corp.
Link-Belt Co.
Morse Boulger Destructor Co.
Reliance Chemicals Corp.

EARTH MOVING EQUIPMENT
Allis-Chalmers Mfg. Co.
Bucyrus-Erie Co.
Oliver Corp.

EJECTORS, PNEUMATIC or STEAM
Blackburn-Smith Mfg. Co., Inc.
Chicago Pump Co.
Economy Pumps, Inc.
Lakeside Engr. Corp.
Smith & Loveless, Inc.
Worthington Corp.
Yeomans Bros. Co.

ELECTRICAL CONTROL EQUIPMENT
Allis-Chalmers Mfg. Co.
Builders-Providence Inc.
Control Corp.
Fischer & Porter Co.
Foxboro Co.
General Electric Co.
General Filter Co.
Hammarlund Mfg. Co.
Healy-Ruff Co.
Minneapolis-Honeywell Regulator Co.
Omega Machine Co.
Smith & Loveless, Inc.
Taller & Cooper, Inc.
Westinghouse Electric Corp.

ELECTRICALLY OPERATED GATE VALVES
(See Valves, Motor Operated)

ELEVATING AND CONVEYING EQUIPMENT
(See Conveyors and Conveying Equipment)

ENGINE-GENERATOR UNIT
Alco Products Inc.
Allis-Chalmers Mfg. Co.
Climax Engine & Pump Mfg. Co.
Fairbanks Morse & Co.
Homelite Div.
Le Roi Div.,
White Diesel Engine Div.
Worthington Corp.

ENGINES DIESEL
Alco Products Inc.
Allis-Chalmers Mfg. Co.
Fairbanks Morse & Co.
Oliver Corp.
White Diesel Engine Div.
Worthington Corp.

ENGINES, DUAL FUEL
Alco Products Inc.
Allis-Chalmers Mfg. Co.
Fairbanks Morse & Co.
Le Roi Div.
White Diesel Engine Div.
Worthington Corp.

ENGINES (Gas and Gasoline)
Allis-Chalmers Mfg. Co.
Climax Engine & Pump Mfg. Co.
Fairbanks Morse & Co.
Le Roi Div.
Oliver Corp.
White Diesel Engine Div.
Worthington Corp.

ENGINES, SLUDGE GAS
Climax Engine & Pump Mfg. Co.
Fairbanks Morse & Co.
Le Roi Div.
White Diesel Engine Div.
Worthington Corp.

EXHAUSTERS, AIR
(See Pump, Vacuum)

EXPANSION JOINTS—PIPE
(See Joints—Expansion, Pipe)

FANS, EXHAUST AND VENTILATING
Jeffrey Mfg. Co.
Westinghouse Electric Corp.

FEED, CHEMICAL
(See Chemical Feeding Equipment)

FEED WATER HEATERS AND FILTERS
Alco Products, Inc.
Allis-Chalmers Mfg. Co.
American Water Softener Co., Inc.
Graver Water Conditioning Co.
Infilco, Inc.
Lakeside Engr. Corp.

FENCE (Chain Link)
Continental Steel Co.

FERRIC CHLORIDE
Infilco, Inc.
Omega Machine Co.
Pennsylvania Salt Mfg. Co.
Pennsalt of Washington
Proportioneers, Inc.

FERRIC CHLORIDE FEEDERS
(See Chemical Feed and Proportioning Equipment)

FERRIC SULPHATE
Tennessee Corp.

FIBRE PIPE
(See Pipe, Fibre)

FILTER AIDS
Johns-Manville
Modern Swimming Pool Co., Inc.
Proportioneers, Inc.
U. S. Rubber Co.

FILTER ALUM
Consolidated Chemical Industries
General Chemical Div.
Koppers Co., Inc.
Modern Swimming Pool Co., Inc.
Pennsylvania Salt Mfg. Co.

FILTER EQUIPMENT
Allis-Chalmers Mfg. Co.
American Well Works
American Water Softener Co., Inc.
Builders-Providence Inc.
Chemical Equipment Co.
Dorr-Oliver, Inc.
Everson Mfg. Co.
Filtration Equipment Corp.
Fischer & Porter Co.
General Filter Co.
Glenfield & Kennedy, Inc.
Graver Water Conditioning Co.
Hardinge Co., Inc.
Infilco, Inc.
Lakeside Engr. Corp.
Layne & Bowler, Inc.
F. B. Leopold Co., Inc.
Millipore Filter Corp.
Modern Swimming Pool Co., Inc.
Pacific Flush Tank Co.
Permutit Co.
Proportioneers, Inc.
Robert Filter Mfg. Co.
Simplex Valve & Meter Co.
Smith & Loveless, Inc.
Stuart Corp.
Walker Process Equip., Inc.

FILTER MEDIA
American Water Softener Co., Inc.
Anthracite Equipment Corp.
The Carborundum Co.
Graver Water Conditioning Co.
Infilco, Inc.
Johns-Manville
Edward E. Johnson, Inc.
Permutit Co.
Proportioneers, Inc.
Stuart Corp.

FILTER PLATES AND TUBES
American Well Works
The Carborundum Co.
Colonial Plastics Mfg. Co.
Filtros, Inc.

FILTER RATE CONTROLLERS AND GAGES
(See Rate Controllers)

FILTER UNDERDRAINS, SEWAGE
American Well Works
The Carborundum Co.
Filtros, Inc.
Infilco, Inc.
Natco Corp.
Walker Process Equipment, Inc.

FILTER UNDERDRAINS, WATER
American Water Softener Co., Inc.
The Carborundum Co.
Filtration Equipment Corp.
Filtros, Inc.
General Filter Co.
Graver Water Conditioning Co.
Infilco, Inc.
Lakeside Engr. Corp.
F. B. Leopold Co., Inc.
M-C-G Co.
National Clay Pipe Mfrs. Assn.
Permutit Co.
Roberts Filter Mfg. Co.
Stuart Corp.
Walker Process Equip., Inc.

FILTERS VACUUM
Chicago Bridge & Iron Co.
Dorr-Oliver, Inc.
Komline-Sanderson Engineering Corp.
Morse Bros. Mach. Co.
Proportioneers, Inc.

FITTINGS, PIPE, SOLDER TYPE
Crane Co.
Grinnell Co.

FITTINGS, TEES, ELLS, ETC.
Alabama Pipe Co.
Alco Products, Inc.
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
James B. Clow & Sons
Colonial Plastics Mfg. Co.
Continental Can Co.
Crane Co.
Dresser Mfg. Div.
Grinnell Company
M. & H. Valve & Fitting Co.
Mueller Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

FLASH MIXING EQUIPMENT
(See Mixers and Mixing Equipment)

FLEXIBLE JOINTS
(See Joints, Flexible Pipe)

FLOATING COVERS (Digester)
Chicago Pump Co.
Infilco, Inc.
Pacific Flush Tank Co.
Pittsburgh-Des Moines Steel Co.
Walker Process Equip., Inc.

FLOCCULATING EQUIPMENT
American Water Softener Co., Inc.
American Well Works
Chain Belt Co.
Chicago Pump Co.
Dorr-Oliver, Inc.
General Filter Co.
Graver Water Conditioning Co.
Hardinge Co., Inc.
Infilco, Inc.
Jeffrey Mfg. Co.
Lakeside Engr. Corp.
Link-Belt Co.
F. B. Leopold Co., Inc.
Permutit Co.
Reliance Chemicals Corp.
Roberts Filter Mfg. Co.
Smith & Loveless, Inc.
Stuart Corp.
Walker Process Equip., Inc.

FLOW METERS
Bailey Meter Co.
Builders-Providence, Inc.
Chicago Pump Co.
Fischer & Porter Co.
Foster Engineering Co.
Foxboro Co.
Infilco, Inc.
Leupold & Stevens Instruments, Inc.
Minneapolis-Honeywell Regulator Co.
Simplex Valve & Meter Co.
Sparling Meter Co., Inc.

FLOORING
(See Gratings)

FLOW RECORDERS
(See Rate of Flow Recorders)

FLOW REGULATORS
(See Rate of Flow Controllers)

FLUMES, IRON AND STEEL
Bethlehem Steel Co.
Filtration Equipment Corp.
Simplex Valve & Meter Co.

FLUORIDATION CHEMICALS
Chemical Equipment Co.
International Minerals & Chemical Corp.
John Wiley Jones Co.
General Chemical Div.
Tennessee Corp.

FLUORIDATION EQUIPMENT
Chemical Equipment Co.
Fischer & Porter Co.
Infilco, Inc.
Omega Machine Co.
Proportioneers, Inc.
Wallace & Tiernan, Inc.

FORMS AND GASKETS FOR PIPE JOINTS
Johns-Manville
Presstite-Keystone Engr. Products Co.
U. S. Rubber Co.

FURNACES (Melting, Pouring, Ladles, Pots, Etc.)
W. S. Darley & Co.
Hydraulic Development Corp.
Joseph G. Pollard Co., Inc.
Westinghouse Electric Corp.

GAGES (Liquid Level, Pressure Recording)
Bailey Meter Co.
Builders-Providence, Inc.
Crane Co.
Fischer & Porter Co.
Foxboro Co.
Healy-Ruff Co.
Infilco, Inc.
Leupold & Stevens Instruments, Inc.
Minneapolis-Honeywell Regulator Co.
Pacific Flush Tank Co.
Simplex Valve & Meter Co.
Sparling Meter Co., Inc.
Wallace & Tiernan, Inc.

GARBAGE GRINDERS
(See Grinders)

GAS DIFFUSERS
American Well Works
Carborundum Co.
Chicago Pump Co.
Filtros, Inc.
General Filter Co.
Infilco, Inc.
Walker Process Equip., Inc.

GAS ENGINES
(See Engines, Gas)

GAS HOLDERS
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Chicago Pump Co.
Dorr-Oliver, Inc.
Pacific Flush Tank Co.
Pittsburgh-Des Moines Steel Co.
Walker Process Equip., Inc.

GAS INDICATOR AND DETECTORS
Bailey Meter Co.
Fischer & Porter Co.
General Electric Co.
Taller & Cooper, Inc.
Wallace & Tiernan Inc.

GATES, SHEAR
Chapman Valve Mfg. Co.
James B. Clow & Sons
Eddy Valve Co.
Filtration Equipment Corp.
Iowa Valve Co.
Lakeside Engr. Corp.
Ludlow Valve Mfg. Co., Inc.
M. & H. Valve & Fitting Co.
Mueller Co.
Stuart Corp.
Washington Aluminum Co., Inc.

GATES, SLUICE
Chapman Valve Mfg. Co.
Filer & Stowell Co.
Iowa Valve Co.
Ludlow Valve Mfg. Co., Inc.
S. Morgan Smith Co.
Morse Bros. Mach. Co.
Mueller Co.
Rensselaer Valve Div.
Stuart Corp.
Washington Aluminum Co., Inc.

GATE VALVE OPERATOR
Chapman Valve Mfg. Co.
Control Corp.
Darling Valve & Mfg. Co.
Payne Dean & Co.
Eddy Valve Co.
Fischer & Porter Co.
Hagan Corp.
Infilco, Inc.
Iowa Valve Co.
F. B. Leopold Co., Inc.
Ludlow Valve Mfg. Co., Inc.
Mueller Co.
Philadelphia Gear Works, Inc.
Taller & Cooper, Inc.

GATE VALVES
(See Valves, Gate)

GEARS, SPEED REDUCING
De Laval Steam Turbine Co.
Link-Belt Co.
Philadelphia Gear Works, Inc.
U. S. Electrical Motors, Inc.
Westinghouse Electric Corp.
Worthington Corp.

GEIGER COUNTERS
Computer-Measurements Corp.
Joseph G. Pollard Co., Inc.

GENERATOR SETS, GAS AND DIESEL ENGINES
(See Engine Generating Units)

GENERATORS (Electric)
Allis-Chalmers Mfg. Co.
Electric Mach. Mfg. Co.
Fairbanks Morse & Co.
General Electric Co.
Homelite Corp.
Le Roi Div.
Westinghouse Electric Corp.
Worthington Corp.

GOOSENECKS
Grinnell Company
Mueller Co.

GRATINGS, FLOORING, TREADS, RAILINGS
Borden Metal Products
Hollaender Mfg. Co.
Johns-Manville
U. S. Rubber Co.
Washington Aluminum Co.

GREEN SAND
Chemical Equipment Co.
Graver Water Conditioning Co.
Infilco, Inc.
Lakeside Eng. Corp.
Permutit Co.

GRINDERS, GARBAGE AND SCREENINGS
American Well Works
Chain Belt Co.
Dorr-Oliver, Inc.
General Electric Co.
Gruendler Crusher & Pulverizer Co.
Jeffrey Mfg. Co.
Walker Process Equip., Inc.

GRIT CHAMBER EQUIPMENT AND GRIT WASHERS
American Well Works
Beaumont Birch Co.
Chain Belt Co.
Chicago Pump Co.
Dorr-Oliver, Inc.
Graver Water Conditioning Co.
Infilco, Inc.
Jeffrey Mfg. Co.
Link-Belt Co.
Stuart Corp.
Walker Process Equip., Inc.

GROUND KEY STOPS
Ford Meter Box Co., Inc.
Mueller Co.
Safety Gas Main Stopper Co., Inc.

GUNITING CONTRACTING
Cement Gun Co.
Chemical Fire & Rust Proofing Corp.

HEATERS, DIGESTER
Chicago Pump Co.
Dorr-Oliver, Inc.
Infilco, Inc.
Pacific Flush Tank Co.
Walker Process Equip., Inc.

HOSE, STEAM, AIR, WATER, SUCTION
United States Rubber Co.

HYDRANTS (Fire)
James B. Clow & Sons
Darling Valve & Mfg. Co.
Eddy Valve Co.
Iowa Valve Co.
Ludlow Valve Mfg. Co., Inc.
M. & H. Valve & Fitting Co.
Mueller Co.
Rensselaer Valve Div.
A. P. Smith Mfg. Co.
R. D. Wood Co.

HYDRANT PUMPS
(See Pumps, Hydrant)

HYDRAULICALLY OPERATED GATE VALVES
(See Valves, Gate)

HYDROGEN ION EQUIPMENT
(See pH Test Equipment)

HYPOCHLORITES (High Test)
(See Calcium Hypochlorite)

HYPO-CHLORINATORS
American Water Softener Co., Inc.
Chemical Equipment Co.
Fischer & Porter Co.
Olin Mathieson Chemical Corp.
Omega Machine Co.
Proportioneers, Inc.
Wallace & Tiernan, Inc.

INCINERATORS (Sludge and Garbage)
Beaumont Birch Co.
Combustion Engineering, Inc.
Morse Boulger Destructor Co.
Pittsburgh-Des Moines Steel Co.

INDICATORS, LARGE DIAL ILLUMINATED
Bailey Meter Co.
Builders-Providence, Inc.
General Filter Co.
Healy-Ruff Co.
Infilco, Inc.
Leupold & Stevens Instruments, Inc.
Simplex Valve & Meter Co.
Sparling Meter Co., Inc.

INSECTICIDES
Columbia-Southern Chemical Corp.
Diamond Alkali Co.
General Chemical Div.
Koppers Company, Inc.
Pennsylvania Salt Mfg. Co.
Pennsalt of Washington
U. S. Rubber Co.

INSERTING SLEEVES, VALVE
James B. Clow & Sons
Iowa Valve Co.
Ludlow Valve Mfg. Co., Inc.
M. & H. Valve & Fittings Co.
Mueller Co.
A. P. Smith Mfg. Co.

INSULATION
Johns-Manville
J. W. Mortell Co.

IRON SULFATE
(See Ferric Sulfate, or Ferrous Sulfate)

JOINTING COMPOUND AND MATERIALS
W. S. Darley & Co.
Grinnell Company
Hydraulic Development Corp.
Johns-Manville
Keasley & Mattison Co.
Koppers Company, Inc.
Joseph G. Pollard Co., Inc.
Presstite-Keystone Engr. Products Co.

JOINTS, EXPANSION—PIPE
James B. Clow & Sons
Crane Co.
Dresser Mfg. Div.
Johns-Manville
United States Rubber Co.

JOINTS, FLEXIBLE PIPE
American Vitrified Products Co.
Cast Iron Pipe Research Assn.
James B. Clow & Sons
United States Pipe & Foundry Co.

JOINTS, MECHANICAL FLEXIBLE
American Vitrified Products Co.
James B. Clow & Sons
Dresser Mfg. Div.
Grinnell Company
Hamilton Kent Mfg. Co.
United States Pipe & Foundry Co.

JUTE, BRAIDED AND TWISTED
Hydraulic Development Corp.
Joseph G. Pollard Co., Inc.

LABORATORY APPARATUS REAGENTS AND EQUIPMENT
Arnold O. Beckman, Inc.
Bailey Meter Co.
Beckman Instruments, Inc.
Builders-Providence, Inc.
Calgon, Inc.
Fischer & Porter Co.
General Chemical Div., Allied Chemical & Dye Corp.
Hydraulic Development Corp.
Infilco, Inc.
Klett Mfg. Co.
F. B. Leopold Co., Inc.
Millipore Filter Corp.
Minneapolis-Honeywell Regulator Co.
Mueller Co.
Phipps & Bird, Inc.
Proportioneers, Inc.
Taller & Cooper, Inc.
W. A. Taylor & Co.
Wallace & Tiernan, Inc.

LEAK LOCATING INSTRUMENTS
(See Water Leak Locating Instruments)

LINING, TANKS
(See Tanks, Lining)

LIQUID CHLORINE
(See Chlorine, Liquid)

LOCATORS, BOX, PIPE AND VALVE
Joseph G. Pollard Co., Inc.

LUBRICANTS, VALVE
Mueller Co.
Rockwell Mfg. Co.
U. S. Rubber Co.

MANHOLE FRAMES, COVERS
H. W. Clark Co.
James B. Clow & Sons
A. Reed Wilson Co.

MANOMETERS
Builders-Providence, Inc.
Fischer & Porter Co.
Infilco, Inc.
Norwalk Valve Co.
Pacific Flush Tank Co.
Simplex Valve & Meter Co.
Wallace & Tiernan, Inc.

METEOROLOGICAL INSTRUMENTS
Fischer & Porter Co.
Leupold & Stevens Instruments, Inc.

METER ACCESSORIES, BOXES, HOUSING SETTING, ETC.
Alabama Pipe Co.
H. W. Clark Co.
Darling Valve & Mfg. Co.
Ford Meter Box Co., Inc.
Iowa Valve Co.
Mueller Co.

METER CLEANING (Equipment and Chemicals
Bailey Meter Co.

METER COUPLINGS, YOKES
Badger Meter Mfg. Co.
H. W. Clark Co.
Ford Meter Box Co., Inc.
Mueller Co.
Neptune Meter Co.

METER REPAIR PARTS
Badger Meter Mfg. Co.
Hersey Mfg. Co.
Neptune Meter Co.
Worthington-Gamon Meter Div.

METERS, ELECTRIC
Bailey Meter Co.
General Electric Co.
Minneapolis-Honeywell Regulator Co.
Simplex Valve & Meter Co.
Westinghouse Electric Corp.

METERS, FLOW TUBE
Bailey Meter Co.
Builders-Providence, Inc.
Fischer & Porter Co.
Foster Engineering Co.
Foxboro Co.
Minneapolis-Honeywell Regulator Co.
Simplex Valve & Meter Co.
Sparling Meter Co., Inc.

METERS, GAS
Bailey Meter Co.
Builders-Providence, Inc.
Fischer & Porter Co.
Foxboro Co.
Minneapolis-Honeywell Regulator Co.
Neptune Meter Co.
Rockwell Mfg. Co.
Roots-Connersville Blower Div.

METERS (Turbine Type)
Badger Meter Mfg. Co.
Fischer & Porter Co.
Hersey Mfg. Co.
Neptune Meter Co.
Worthington-Gamon Meter Div.

METER TESTING EQUIPMENT
Badger Meter Mfg. Co.
Fischer & Porter Co.
Ford Meter Box Co., Inc.
Hersey Mfg. Co.
Neptune Meter Co.
Rockwell Mfg. Co.

METERS, VENTURI
Bailey Meter Co.
Builders-Providence, Inc.
Fischer & Porter Co.
Foxboro Co.
Infilco, Inc.
Minneapolis-Honeywell Regulator Co.
Simplex Valve & Meter Co.

METERS, WATER (Consumer)
Badger Meter Mfg. Co.
Buffalo Meter Co.
Builders-Providence, Inc.
Hersey Mfg. Co.
Neptune Meter Co.
Rockwell Mfg. Co.
Worthington-Gamon Meter Div.

MIXERS AND MIXING EQUIPMENT
American Well Works
Chain Belt Co.
Graver Water Conditioning Co.
Infilco, Inc.
Jeffrey Mfg. Co.
F. B. Leopold Co., Inc.
Link-Belt Co.
Philadelphia Gear Works, Inc.
Stuart Corp.
Walker Process Equip., Inc.
Western Machinery Co.
Worthington Corp.

MOTORS, ELECTRIC
Allis-Chalmers Mfg. Co.
Electric Mach. Mfg. Co.
Fairbanks Morse & Co.
General Electric Co.
U. S. Electrical Motors, Inc.
Westinghouse Electric Corp.
Worthington Corp.

NOZZLES, FLOW
Bailey Meter Co.
Builders-Providence, Inc.
Foxboro Co.
Simplex Valve & Meter Co.

NOZZLES, SPRAY (Water and Sewage)
Carborundum Co.
Chain Belt Co.
Grinnell Company
Infilco, Inc.
Link-Belt Co.
Lakeside Engr. Corp.
Pacific Flush Tank Co.
Worthington Corp.
Yeomans Bros. Co.

OPERATING TABLES (Filter)
American Water Softener Co., Inc.
Bailey Meter Co.
Builders-Providence, Inc.
Filtration Equipment Corp.
Foxboro Co.
General Filter Co.
Graver Water Conditioning Co.
Infilco, Inc.
F. B. Leopold Co., Inc.
Minneapolis-Honeywell Regulator Co.
Permutit Co.
Roberts Filter Mfg. Co.
Simplex Valve & Meter Co.
Walker Process Equip., Inc.

ORIFICES
Bailey Meter Co.
Builders-Providence, Inc.
Fischer & Porter Co.
Foxboro Co.
General Filter Co.
Grinnell Co.
Infilco, Inc.
F. B. Leopold Co., Inc.
Minneapolis-Honeywell Regulator Co.
Simplex Valve & Meter Co.
Wallace & Tiernan, Inc.
Worthington Corp.

PACKING (Pumps and Valves)
Johns-Manville
United States Rubber Co.

PAINT (Acid Resisting)
Amercoat Corp.
Hercules Powder Co., Inc.
Koppers Co., Inc.
J. W. Mortell Co.
Pennsylvania Salt Mfg. Co.
Pittsburgh Coke & Chemical Co.
U. S. Rubber Co.

PENSTOCKS
Alco Products, Inc.
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
R. D. Cole Mfg. Co.
Hammond Iron Works
Nooter Corp.
Pittsburgh-Des Moines Steel Co.
Westinghouse Electric Corp.

pH TEST EQUIPMENT
Allis-Chalmers Mfg. Co.
Bailey Meter Co.
Beckman Instruments, Inc.
Infilco, Inc.
Modern Swimming Pool Co., Inc.
Permutit Co.
Phipps & Bird, Inc.
W. A. Taylor & Co.
Wallace & Tiernan, Inc.

PHOTOELECTRIC COLORIMETERS
Beckman Instruments, Inc.
Phipps & Bird, Inc.
W. A. Taylor & Co.

PIPE AND FITTINGS, LINED
Alco Products, Inc.
American Cast Iron Pipe
American Hard Rubber Co.
Bethlehem Steel Co.
Cast Iron Pipe Research Assn.
Chemical Equipment Co.
James B. Clow & Sons
Crane Co.
Grinnell Co.
United States Pipe & Foundry Co.
United States Rubber Co.

PIPE AND TANK COATINGS
Amercoat Corp.
Cement Gun Co., Inc.
Chemical Fire & Rust Proofing Corp.
Koppers Co., Inc.
Johns-Manville
J. W. Mortell Co.
Pennsylvania Salt Mfg. Co.
U. S. Rubber Co.

PIPE, ASBESTOS-CEMENT
Johns-Manville
Keasbey & Mattison Co.

PIPE, CAST IRON
Alabama Pipe Co.
American Cast Iron Pipe
Cast Iron Pipe Research Assn.
James B. Clow & Sons
Combustion Engineering, Inc.
United States Pipe & Foundry Co.
R. D. Wood Co.
Woodward Iron Co.

PIPE, CEMENT LINED
Alabama Pipe Co.
American Cast Iron Pipe
Cast Iron Pipe Research Assn.
James B. Clow & Sons
United States Pipe & Foundry Co.
R. D. Wood Co.

PIPE, CEMENT LINING OF
Centriline Corp.
James B. Clow & Sons
Standard Dry Wall Products, Inc.

PIPE, CONCRETE, PRESSURE
American Concrete Pressure Pipe Assoc.
Preload Co., Inc.
Lock Joint Pipe Co.
Price Bros. Co.

PIPE, COPPER, BRASS AND BRONZE
Mueller Co.

PIPE, CULVERT
American Vitrified Products Co.
James B. Clow & Sons
Nooter Corp.
Price Bros. Co.
R. D. Wood Co.

PIPE CUTTING MACHINES
Ellis & Ford Mfg. Co., Inc.
Prescott Tool Co., Inc.
A. P. Smith Mfg. Co.
Spring Load Mfg. Co.

PIPE ENAMELS, PROTECTIVE—COAL TAR
Alco Products, Inc.
Koppers Co., Inc.
J. W. Mortell Co.

PIPE FITTINGS
(See Fittings)

PIPE, HARD RUBBER LINED
(See Rubber Lined Pipe and Valves)

PIPE JOINT COMPOUNDS
(See Jointing Compounds)

PIPE JOINT PACKING
Hydraulic Development Corp.
Johns-Manville
Keasbey & Mattison Co.
Presstite-Keystone Engr. Products Co.

PIPE JOINTS (Mechanical)
American Vitrified Products Co.
Cast Iron Pipe Research Assn.
James B. Clow & Sons
Dresser Mfg. Div.
Grinnell Company
United States Pipe & Foundry Co.
U. S. Rubber Co.
R. D. Wood Co.

PIPE JOINT TOOLS
W. S. Darley & Co.
Hydraulic Development Corp.
Mueller Co.
Joseph G. Pollard Co., Inc.

PIPE LOCATORS
Computer-Measurements Corp.
W. S. Darley & Co.
Joseph G. Pollard Co., Inc.
Filtration Equipment Corp.
Wilkinson Products Co.

PIPE, PLASTIC
American Hard Rubber Co.
Chemical Equipment Co.
Colonial Plastics Mfg. Co.
Continental Can Co.
Crane Co.
United States Rubber Co.
Westinghouse Electric Corp.

PIPE, SEWER
Alco Products, Inc.
American Vitrified Products Co.
Bethlehem Steel Co.
James B. Clow & Sons
Johns-Manville
Keasbey & Mattison Co.
Natco Corp.
National Clay Pipe, Inc.
Price Bros. Co.
United States Pipe & Foundry Co.

PIPE, STEEL (All Types)
Alco Products, Inc.
Bethlehem Steel Co.

PIPE TAPPING MACHINES
Mueller Co.
A. P. Smith Mfg. Co.

PIPE TEST PLUGS
James B. Clow & Sons
W. S. Darley & Co.
Eddy Valve Co.
Ellis & Ford Mfg. Co., Inc.
Flexible Inc.
Joseph G. Pollard Co., Inc.
A. P. Smith Mfg. Co.

PIPE THAWING, ELECTRICAL, STEAM, FLAME
W. S. Darley & Co.
Joseph G. Pollard Co., Inc.

PIPE TOOLS (Asbestos, Cement)
Keasbey & Mattison Co.
Spring Load Mfg. Co.

PIPE TOOLS (Cutters, Extractors, Threaders, Wrenches, Etc.)
Flexible, Inc.
Joseph G. Pollard Co., Inc.

PIPE, VITRIFIED CLAY
(See Vitrified Clay Pipe and Products)

PIPE WRAPPING
Chemical Fire & Rust Proofing Corp.
Johns-Manville
J. W. Mortell Co.

PIPE, WROUGHT IRON
A. M. Byers Co.

PITOT TUBES
Foxboro Co.
Simplex Valve & Meter Co.

PLASTIC PIPE AND TUBING
(See Pipe Plastic)

PNEUMATIC CONVEYORS
(See Conveyors and Conveying Equipment)

POROUS TUBES AND PLATES
American Well Works
The Carborundum Co.
Filtros, Inc.
Walker Process Equip., Inc.

POWER TAKE-OFF (Truck Type)
Payne Dean & Co.

PRESSURE REGULATORS
(See Regulators, Pressure)

PRESTRESSED CONCRETE TANKS
Cement Gun Co., Inc.
Preload Co., Inc.

PROPORTIONING EQUIPMENT
(See Chemical Feed and Proportioning Equipment)

PUMPING CONTROLS
Allis-Chalmers Mfg. Co.
Bailey Meter Co.
Builders-Providence, Inc.
Chicago Pump Co.
Ernest Bernard Electric Co.
Fischer & Porter Co.
General Electric Co.
Hammarlund Mfg. Co.
Healy-Ruff Co.
Minneapolis-Honeywell Regulator Co.
Smith & Loveless, Inc.
Taller & Cooper, Inc.

PUMP PRIMERS
Chicago Pump Co.
Smith & Loveless, Inc.

PUMPS, ACID-HANDLING
Allis-Chalmers Mfg. Co.
American Hard Rubber Co.
Aurora Pump Div.
De Laval Steam Turbine Co.
Dorr-Oliver, Inc.
Economy Pumps, Inc.
Fischer & Porter Co.
Johnston Pump Co.
Komline-Sanderson Engineering Corp.
Peerless Pump Div.
Wallace & Tiernan, Inc.
Weinman Pump Mfg. Co.
Worthington Corp.
Yeomans Bros. Co.

PUMPS, CELLAR DRAINER
(See Pumps, Sump)

PUMPS, CENTRIFUGAL
Allis-Chalmers Mfg. Co.
American Well Works
Aurora Pump Div.
Chain Belt Co.
Chicago Pump Co.
W. S. Darley & Co.
De Laval Steam Turbine Co.
Dorr-Oliver, Inc.
Economy Pump, Inc.
Fairbanks Morse & Co.
Homelite Div.
Peerless Pump Div.
Roots-Connerville Blower Div.
Weil Pump Co.
Weinman Pump Mfg. Co.
Western Machinery Co.
Worthington Corp.
Yeomans Bros. Co.

PUMPS, DEEP WELL
American Well Works
Aurora Pump Div.
Byron Jackson Div.

Fairbanks Morse & Co.
Johnston Pump Co.
Layne & Bowler, Inc.
Peerless Pump Div.
Worthington Corp.

PUMPS, DIAPHRAGM
Chain Belt Co.
Dorr-Oliver, Inc.
Fischer & Porter Co.
Homelite Div.
Komline-Sanderson Engineering Corp.
Morse Bros. Machinery Co.
Joseph G. Pollard Co., Inc.
Permutit Co.
Proportioneers, Inc.
Wallace & Tiernan, Inc.
Western Machinery Co.

PUMPS, DRAINAGE
(See Pumps, Sewage and Drainage)

PUMPS, HYDRANT
W. S. Darley & Co.
Ellis & Ford Mfg. Co., Inc.
Joseph G. Pollard Co., Inc.

PUMPS, HYDRAULIC (Pressure Boosting)
De Laval Steam Turbine Co.
Economy Pumps, Inc.
Rockwell Mfg. Co.
Weinman Pump Mfg. Co.
Worthington Corp.

PUMPS, PORTABLE
Aurora Pump Div.
Chain Belt Co.
W. S. Darley & Co.
Fairbanks Morse & Co.
Homelite Div.
Peerless Pump Div.
Worthington Corp.

PUMPS, ROTARY
De Laval Steam Turbine Co.
Fairbanks Morse & Co.
Roots-Connersville Blower Div.
Worthington Corp.

PUMPS, SELF-PRIMING
Aurora Pump Div.
Chain Belt Co.
W. S. Darley & Co.
De Laval Steam Turbine Co.
Fairbanks Morse & Co.
Homelite Div.
Johnston Pump Co.
Peerless Pump Div.
Roots-Connersville Blower
Worthington Corp.

PUMPS, SEWAGE AND DRAINAGE
Allis-Chalmers Mfg. Co.
American Well Works
Aurora Pump Div.
Chain Belt Co.
Chicago Pump Co.
Dorr-Oliver, Inc.
Economy Pump, Inc.
Fairbanks Morse & Co.
Layne & Bowler, Inc.
Peerless Pump Div.
Weil Pump Co.
Weinman Pump Mfg. Co.
Western Machinery Co.
Worthington Corp.
Yeomans Bros. Co.

PUMPS, SLUDGE
Allis-Chalmers Mfg. Co.
American Well Works
Aurora Pump Div.
Chicago Pump Co.
Dorr-Oliver, Inc.
Economy Pump, Inc.
Fairbanks Morse & Co.
Infilco, Inc.
Komline-Sanderson Engineering Corp.
Lakeside Engr. Corp.
Peerless Pump Div.
Walker Process Equip., Inc.
Western Machinery Co.
Worthington Corp.
Yeomans Bros. Co.

PUMPS, SUMP (AND CELLAR DRAINER)
Aurora Pump Div.
Byron Jackson Div.
Chicago Pump Co.
Economy Pumps, Inc.
Fairbanks Morse & Co.
Johnston Pump Co.
Peerless Pump Div.
Weil Pump Co.
Weinman Pump Mfg. Co.
Western Machinery Co.
Worthington Corp.
Yeomans Bros. Co.

PUMPS, TURBINE
American Well Works
Aurora Pump Div.
Fairbanks Morse & Co.
Johnston Pump Co.
Layne & Bowler, Inc.
Peerless Pump Div.
Weil Pump Co.
Worthington Corp.

PUMPS, VACUUM
Allis-Chalmers Mfg. Co.
Chicago Pump Co.
Dorr-Oliver, Inc.
Economy Pumps, Inc.
Phipps & Bird, Inc.
Roots-Connersville Blower Div.
Worthington Corp.
Yeomans Bros. Co.

RAIN GAGES
(See Meteorological Instrument)

RATE OF FLOW CONTROLLERS
Badger Meter Mfg. Co.
Bailey Meter Co.
Builders-Providence, Inc.
Control Corp.
Fischer & Porter Co.
Foxboro Co.
General Filter Co.
Hagan Corp.
Infilco, Inc.
Minneapolis-Honeywell Regulator Co.
Simplex Valve & Meter Co.
Sparling Meter Co., Inc.

RATE OF FLOW RECORDERS
Badger Meter Mfg. Co.
Bailey Meter Co.
Builders-Providence, Inc.
Control Corp.
Fischer & Porter Co.
Foxboro Co.
General Filter Co.
Hagan Corp.
Infilco, Inc.
Leupold & Stevens Instruments, Inc.
Minneapolis-Honeywell Regulator Co.
Simplex Valve & Meter Co.
Sparling Meter Co., Inc.

RECARBONATORS
(See Carbonators)

REFRACTORIES
The Carborundum Co.
Johns-Manville

REGULATORS, PRESSURE (Water and Gas)
Bailey Meter Co.
Fisher & Porter Co.
Foster Engineering Co.
Control Corp.
Minneapolis- Honeywell Regulator Co.
Mueller Co.
Norwalk Valve Co.
S. Morgan Smith Co.
Rockwell Mfg. Co.
Wallace & Tiernan, Inc.

RESERVOIRS, STEEL
(See Tanks and Standpipes)

RESIDUAL CHLORINE CONTROLLERS
Builders-Providence Inc.
Everson Mfg. Co.
W. A. Taylor & Co.
Wallace & Tiernan, Inc.

RESIDUAL CHLORINE TEST APPARATUS
Modern Swimming Pool Co., Inc.
Phipps & Bird, Inc.
W. A. Taylor & Co.
Wallace & Tiernan, Inc.

ROOF COATINGS
Johns-Manville
Koppers Co., Inc.
Pressitite-Keystone Engr. Products Co.
U. S. Rubber Co.

RUBBER LINED PIPES AND VALVES
American Hard Rubber Co.
Darling Valve & Mfg. Co.
Grinnell Company
United States Rubber Co.
W. S. Rockwell Co.

RUBBER PACKING GASKETS
Hamilton Kent Mfg. Co.
Johns-Manville
United States Rubber Co.

RUST PREVENTION (Water Treatment)
Calgon, Inc.
Graver Water Conditioning Co.
Philadelphia Quartz Co.
Smith & Loveless, Inc.
Proportioneers Inc.

SADDLES, PIPE
James B. Clow & Sons
Dresser Mfg. Div.
Grinnell Co.
Mueller Co.
Price Bros. Co.

SAMPLERS AND SAMPLING TABLES
Builders-Providence, Inc.
Infilco, Inc.
Lakeside Engr. Corp.
F. B. Leopold Co., Inc.
Phipps & Bird, Inc.
Proportioneers Inc.
Walker Process Equip., Inc.

SAND EXPANSION INDICATORS
Bailey Meter Co.
Builders-Providence, Inc.
Infilco, Inc.
Minneapolis-Honeywell Regulator Co.
Simplex Valve & Meter Co.

SCALES, SLUDGE CONVEYOR
Builders-Providence, Inc.
Fairbanks Morse & Co.

SCREENING AND COMMINUTING
(See Comminuting Devices)

SCREENINGS GRINDERS
(See Grinders)

SCREENS, INTAKE
Chain Belt Co.
Cook Well Strainer Co.
Jeffrey Mfg. Co.
Link-Belt Co.
S. Morgan Smith Co.
Washington Aluminum Co.

SCREENS, SEWAGE
American Well Works
Chain Belt Co.
Dorr-Oliver, Inc.
Infilco, Inc.
Jeffrey Mfg. Co.
Link-Belt Co.
Walker Process Equip., Inc.

SCREENS, VIBRATING
Allis-Chalmers Mfg. Co.
Gruendler Crusher & Pulverizer Co.
Jeffrey Mfg. Co.
Link-Belt Co.

SCREEN, WATER WELL
Cook Well Strainer Co.
Edward E. Johnson, Inc.
Layne & Bowler, Inc.

SCUM REMOVERS
(See Clarifiers)

SEGMENT BLOCKS AND PIPE LINER PLATES (Vitrified)
American Vitrified Products Co.
Natco Corp.
National Clay Pipe Inc.

SERVICE BOXES (Water)
H. W. Clark Co.
James B. Clow & Sons
Ford Meter Box Co., Inc.
Mueller Co.

SEWAGE EJECTORS
See Ejectors, Pneumatic)

SEWAGE SAMPLERS
Chicago Pump Co.
Dezurik Shower Co.
Infilco, Inc.
Lakeside Engr. Corp.
Phipps & Bird, Inc.
Proportioneers, Inc.
Walker Process Equip., Inc.

SEWAGE SLUDGE DRYERS
See Drying Systems, Sludge)

SEWAGE SLUDGE INCINERATORS
(See Incinerators)

SEWER CLEANING EQUIPMENT AND SERVICE
Champion Corp.
Flexible Pipe Cleaning Co.
Flexible, Inc.
National Power Rodding Corp.

SEWER PIPE
(See Pipe, Sewer)

SEWER PIPE JOINTS (and Jointing Compounds)
American Vitrified Products Co.
Grinnell Co.
Hydraulic Development Corp.
Johns-Manville
Koppers Co., Inc.
National Clay Pipe Inc.
Pressitite-Keystone Engr. Products Co.

SEWER RODS
Flexible Inc.

SIPHONS (Sewage Dosing)
American Well Woks
Infilco, Inc.
Pacific Flush Tank Co.
Price Bros. Co.
Smith & Loveless, Inc.
Walker Process Equip., Inc.

SLEEVES, PIPE REPAIR
American Cast Iron Pipe Co.
James B. Clow & Sons
Dresser Mfg. Div.
Eddy Valve Co.
M. & H. Valve & Fittings Co.
Mueller Co.
A. P. Smith Mfg. Co.

SLEEVES, TAPPING (Valve)
James B. Clow & Sons
Darling Valve & Mfg. Co.
Eddy Valve Co.
Ludlow Valve Mfg. Co. Inc.
M. & H. Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.

SLUDGE COLLECTORS
American Well Works
Chain Belt Co.
Chicago Pump Co.
Dorr-Oliver, Inc.
General Filter Co.
Graver Water Conditioning Co.
Hardinge Co., Inc.
Jeffrey Mfg. Co.
Lakeside Engr. Corp.
Link-Belt Co.
Stuart Corp.
Walker Process Equip., Inc.

SLUDGE DISINTEGRATORS
Dorr-Oliver, Inc.
Gruendler Crusher & Pulverizer Co.
Jeffrey Mfg. Co.
Royer Foundry & Machine Co.

SLUDGE DRYERS
(See Drying Systems)

SLUDGE EJECTORS
(See Ejectors, Pneumatic)

SLUDGE GAS ENGINES
(See Engines, Sludge Gas)

SLUDGE INCINERATORS
(See Incinerators)

SLUDGE PUMPS
(See Pumps, Sludge)

SLUDGE SAMPLERS
Infilco, Inc.
Jeffrey Mfg. Co.
Phipps & Bird, Inc.
Walker Process Equip., Inc.

SLUDGE VALVES (Telescopic)
ACF Industries, Inc.
American Well Works
Chain Belt Co.
Dezurik Shower Co.
Roberts Filter Mfg. Co.
Rockwell Mfg. Co.
Walker Process Equip., Inc.

SODA ASH
Columbia-Southern Chemical Corp.
Diamond Alkali Co.
Olin Mathieson Chemical Corp.
Niagara Alkali Co.

SODIUM BISULPHITE
General Chemical Div.

SODIUM HYPOCHLORITE
John Wiley Jones Co.
Olin Mathieson Chemical Corp.
Pennsylvania Salt Mfg. Co.
Pennsalt of Washington
Wallace & Tierman, Inc.

SODIUM PHOSPHATES (Glassy)
Calgon, Inc.
General Chemical Div.
Pennsylvania Salt Mfg. Co.
Pennsalt of Washington

SODIUM SILICATE
Diamond Alkali Co.
General Chemical Div.
Philadelphia Quartz Co.

SOFTENERS
(See Water Softening Equipment)

SPEED REDUCERS, TRANSMISSION
Allis-Chalmers Mfg. Co.
De Laval Steam Turbine Co.
Link-Belt Co.
Philadelphia Gear Works Inc.
U. S. Electrical Motors Inc.

SPRINKLING FILTER EQUIPMENT
(See Trickling Filter Equipment)

SPRINKLING FILTER UNDERDRAINS
(See Filter Underdrains, Sewage)

STACKS
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
R. D. Cole Mfg. Co.
Hammond Iron Works
Johns-Manville
Pittsburgh-Des Moines Steel Co.

STANDPIPES
(See Tanks and Standpipes)

STIRRERS (Laboratory)
Infilco, Inc.
Phipps & Bird, Inc.

STOKERS
Combustion Engineering, Inc.
Fairbanks Morse & Co.

STRAINERS—SUCTION
Blackburn-Smith Mfg. Co., Inc.
W. S. Darley & Co.
Glenfield & Kennedy, Inc.
Layne & Bowler, Inc.
S. Morgan Smith Co.

SULPHATE OF ALUMINA
(See Filter Alum)

SULPHUR DIOXIDE (Liquid)
General Chemical Div.
Tennessee Corp.

SWITCHBOARD AND SWITCH GEAR
Allis-Chalmers Mfg. Co.
Blackburn-Smith Mfg. Co., Inc.
Electric Mach. Mfg. Co.
General Electric Co.
Westinghouse Electric Corp.
Worthington Corp.

TANK LININGS
Amercoat Corp.
Cement Gun Co., Inc.
Chemical Equipment Co.
Chemical Fire and Rust Proofing Corp.
Colonial Plastics Mfg. Co.
General Filter Co.
Koppers Co., Inc.
Natco Corp.
Speelmon Elevated Tank Service
Smith & Loveless, Inc.
United States Rubber Co.

TANK MAINTENANCE AND REPAIR
Cement Gun Co., Inc.
J. W. Mortell Co.
Nooter Corp.
Speelmon Elevated Tank Service

TANKS AND STANDPIPES
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
R. D. Cole Mfg. Co.
Graver Water Conditioning Co.
Hammond Iron Works
Nooter Corp.
Pittsburgh-Des Moines Steel Co.
Preload Co., Inc.

TANKS, RUBBER LINED
American Hard Rubber Co.
Chemical Equipment Co.
Chicago Bridge & Iron Co.
R. D. Cole Mfg. Co.
Graver Water Conditioning Co.
Hammond Iron Works
Pittsburgh-Des Moines Steel Co.
United States Rubber Co.

TAPPING MACHINES
Mueller Co.
A. P. Smith Mfg. Co.

TASTE AND ODOR REMOVAL CHEMICALS
General Chemical Div.
Infilco, Inc.
John Wiley Jones Co.
Permutit Co.
Phelps Dodge Refining Corp.
Wallace & Tiernan, Inc.
West Virginia Pulp & Paper Co.

TESTERS (Water Meter)
Ford Meter Box Co., Inc.
Hersey Mfg. Co.

THICKENERS (SLUDGE)
American Well Works
Chain Belt Co.
Dorr-Oliver, Inc.
Graver Water Conditioning Co.
Hardinge Co., Inc.
Infilco Inc.
Jeffrey Mfg. Co.
Lakeside Engr. Corp.
Link-Belt Co.
Tennessee Corp.
Walker Process Equip., Inc.
Western Machinery Co.

TOOLS, PIPE
(See Pipe Tools)

TOOLS, PNEUMATIC
Le Roi Div.
Schramm Inc.
Worthington Corp.

TRACTORS, BULLDOZERS, ETC.
Allis-Chalmers Mfg. Co.
Oliver Corp.

TRANSFORMERS, ELECTRIC
Allis-Chalmers Mfg. Co.
General Electric Co.
Westinghouse Electric Corp.

TRAPS, DRIP, FLAME, SEDIMENT, STEAM
Crane Co.
Economy Pumps, Inc.
General Electric Co.
Neptune Meter Co.
Pacific Flush Tank Co.

TRENCHING EQUIPMENT
Bucyrus-Erie
Cleveland Trencher Co.
Oliver Corp.

TRICKLING FILTER EQUIPMENT
American Well Works
Dorr-Oliver, Inc.
General Filter Co.
Infilco, Inc.
Lakeside Engr. Corp.
Natco Corp.
Pacific Flush Tank Co.
Smith & Loveless, Inc.
Walker Process Equip., Inc.
Yeomans Bros. Co.

TRICKLING FILTER UNDERDRAINS
(See Filter Underdrains)

TURBIDIMETERS
Bailey Meter Co.
Beckman Instruments Inc.
General Electric Co.
Infilco, Inc.
Klett Mfg. Co.
Phipps & Bird, Inc.

TURBINES, HYDRAULIC
Allis-Chalmers Mfg. Co.
S. Morgan Smith Co.

TURBINES, STEAM
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.
General Electric Co.
Westinghouse Electric Corp.
Worthington Corp.

UNDERGROUND PUMPING STATIONS
Smith & Loveless, Inc.
Zimmer And Francescon

VACUUM FILTERS
Chicago Bridge & Iron Co.
Dorr-Oliver, Inc.
Komline-Sanderson Engineering Corp.
Proportioneers Inc.

VALVE BOXES
Alabama Pipe Co.
James B. Clow & Sons
Dezurik Shower Co.
Eddy Valve Co.
Filtration Equipment Corp.
Ford Meter Box Co., Inc.
Iowa Valve Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Div.
A. P. Smith Mfg. Co.
R. D. Wood Co.

VALVE BOX LOCATORS
Computer-Measurements Corp.
W. S. Darley & Co.
Joseph G. Pollard Co., Inc.

VALVE INSERTING MACHINES
Mueller Co.
A. P. Smith Mfg. Co.
Taller & Cooper, Inc.

VALVE OPERATOR
(See Gate Valve Operator)

VALVES, AIR RELEASE AND VACUUM BREAKING
Darling Valve & Mfg. Co.
Eddy Valve Co.
Foster Engineering Co.
Ludlow Valve Mfg. Co., Inc.
Multiplex Mfg. Co.
Rensselaer Valve Div.
Simplex Valve & Meter Co.

VALVES, ALTITUDE
Chapman Valve Mfg. Co.
Foster Engineering Co.
Golden—Anderson Valve Specialty Co.
Henry Pratt Co.
S. Morgan Smith Co.

VALVES, BUTTERFLY
Allis-Chalmers Mfg. Co.
Builders-Providence, Inc.
Chapman Valve Mfg. Co.
Foster Engineering Co.
Foxboro Co.
F. B. Leopold Co. Inc.
Ludlow Valve Mfg. Co., Inc.
Minneapolis-Honeywell Regulator Co.
Henry Pratt Co.
W. S. Rockwell Co.
S. Morgan Smith Co.
Westinghouse Electric Corp.
Worthington Corp.

VALVES, CHECK
ACF Industries, Inc.
Chapman Valve Mfg. Co.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
Eddy Valve Co.
Golden-Anderson Valve Specialty Co.
Grinnell Company
Hersey Mfg. Co.
Iowa Valve Co.
Jeffrey Mfg. Co.
Ludlow Valve Mfg., Co. Inc.
M. & H. Valve & Fittings Co.
Mueller Co.
Norwalk Valve Co.
Pacific Flush Tank Co.
Rensselaer Valve Div.
W. S. Rockwell Co.
A. P. Smith Mfg. Co.
S. Morgan Smith Co.

VALVES, CHLORINE
Chemical Equipment Co.
Crane Co.
Darling Valve & Mfg. Co.
Fischer & Porter Co.
Grinnell Co.
Homestead Valve Mfg. Co.
Wallace & Tierman Inc.

VALVES, CONE
Chapman Valve Mfg. Co.
Golden-Anderson Valve Specialty
Homestead Valve Mfg. Co.
Rockwell Mfg. Co.
S. Morgan Smith Co.

VALVES, DIAPHRAGM
Bailey Meter Co.
Colonial Plastics Mfg. Co.
Crane Co.
Darling Valve & Mfg. Co.
Fischer & Porter Co.
Foster Engineering Co.
Foxboro Co.
Grinnell Company
Infilco Inc.
Minneapolis-Honeywell Regulator Co.
S. Morgan Smith Co.
Taller & Cooper, Inc.

VALVES, ELECTRICALLY OPERATED
(See Valves, Motor Operated)

VALVES, FLAP
Chapman Valve Mfg. Co.
James B. Clow & Sons
Eddy Valve Co.
Iowa Valve Co.
Ludlow Valve Mfg. Co., Inc.
M. & H. Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Div.

VALVES FLOAT
Eddy Valve Co.
Foster Engineering Co.
Golden-Anderson Valve Specialty Co.
Lakeside Engr. Corp.
Ludlow Valve Mfg. Co., Inc.
Multiplex Mfg. Co. Inc.
Henry Pratt Co.
S. Morgan Smith Co.
W. S. Rockwell Co.

VALVES, FOOT
Chapman Valve Mfg. Co.
Crane Co.
Eddy Valve Co.
Grinnell Co.
Ludlow Valve Mfg. Co., Inc.
Rensselaer Valve Div.

VALVES, FOUR WAY
Crane Co.
Dezurik Shower Co.
Homestead Valve Mfg. Co.
Infilco, Inc.
F. B. Leopold Co., Inc.
Ludlow Valve Mfg. Co., Inc.
Rockwell Mfg. Co.

VALVES, GATE
Chapman Valve Mfg. Co.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
DeZurik Shower Co.
Eddy Valve Co.
Filer & Stowell Co.
Fischer & Porter Co.
Iowa Valve Co.
Jeffrey Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M. & H. Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Div.
W. S. Rockwell Co.
A. P. Smith Mfg. Co.
Westinghouse Electric Corp.
R. D. Wood Co.
Worthington Corp.

VALVES, HYDRAULIC CYLINDER OPERATED
Builders-Providence, Inc.
Chapman Valve Mfg. Co.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
Dezurik Shower Co.
Eddy Valve Co.
Filer & Stowell Co.
Fisher & Porter Co.
Golden-Anderson Valve Specialty Co.
Grinnell Company
Homestead Valve Mfg. Co.
Iowa Valve Co.
Ludlow Valve Mfg. Co., Inc.
M. & H. Valve & Fittings Co.
Philadelphia Gear Works Inc.
Henry Pratt Co.
Rensselaer Valve Div.
Rockwell Mfg. Co.
W. S. Rockwell Co.
A. P. Smith Mfg. Co.
S. Morgan Smith Co.

VALVES, LUBRICATED PLUG
ACF Industries, Inc.
Homestead Valve Mfg. Co.
F. B. Leopold Co., Inc.
Rockwell Mfg. Co.
W-K-M Mfg. Co., Inc.

VALVES, MECHANICAL JOINT
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
Dezurik Shower Co.
Eddy Valve Co.
Iowa Valve Co.
Ludlow Valve Mfg. Co., Inc.
M. & H. Valve & Fittings Co.
Mueller Co.
Henry Pratt Co.
Rensselaer Valve Div.
Rockwell Mfg. Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

VALVES, MOTOR OPERATED
ACF Industries, Inc.
Builders-Providence Inc.
Chapman Valve Mfg. Co.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
Dezurik Shower Co.
Eddy Valve Co.
Filer & Stowell Co.
Fischer & Porter Co.
Golden-Anderson Valve Specialty Co.
Homestead Valve Mfg. Co.
Infilco, Inc.
Iowa Valve Co.
Ludlow Valve Mfg. Co., Inc.
M. & H. Valve & Fittings Co.
Minneapolis-Honeywell Regulator Co.
Mueller Co.
Payne Dean & Co.
Permutit Co.
Philadelphia Gear Works, Inc.
Henry Pratt Co.
Rensselaer Valve Div.
Rockwell Mfg. Co.
W. S. Rockwell Co.
A. P. Smith Mfg. Co.
S. Morgan Smith Co.
Taller & Cooper, Inc.
Westinghouse Electric Corp.

VALVES, MUD AND PLUG
ACF Industries, Inc.
Chapman Valve Mfg. Co.
James B. Clow & Sons
Dezurik Shower Co.
Eddy Valve Co.
Filer & Stowell Co.
Homestead Valve Mfg. Co.
Iowa Valve Co.
Ludlow Valve Mfg. Co., Inc.
M. & H. Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Div.
Roberts Filter Mfg. Co.
Rockwell Mfg. Co.

VALVES, PRESSURE REDUCING
Bailey Meter Co.
Crane Co.
Foster Engineering Co.
Golden-Anderson Valve Specialty Co.
Minneapolis-Honeywell Regulator Co.
Mueller Co.
S. Morgan Smith Co.

VALVES, RELIEF
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
Eddy Valve Co.
Foster Engineering Co.
Golden-Anderson Valve Specialty Co.
Mueller Co.
Multiplex Mfg. Co.
Pacific Flush Tank Co.
Norwalk Valve Co.
Simplex Valve & Meter Co.
S. Morgan Smith Co.

VALVES (Rubber, Plastic, Glass or Lead)
American Hard Rubber Co.
Chemical Equipment Co.
Colonial Plastics Mfg. Co.
Crane Co.
Darling Valve & Mfg. Co.
Dezurik Shower Co.
Golden-Anderson Valve Specialty Co.
Grinnell Company
U. S. Rubber Co.

VALVES, SPECIAL, AUTOMATIC (Including Remote Control)
ACF Industries, Inc.
American Water Softener Co., Inc.
Bailey Meter Co.
Builders-Providence Inc.
Chapman Valve Mfg. Co.
Darling Valve & Mfg. Co.
DeZurik Shower Co.
Eddy Valve Co.
Fischer & Porter Co.
Foster Engineering Co.
Foxboro Co.
Golden-Anderson Valve Specialty Co.
Grinnell Company
Infilco, Inc.
Ludlow Valve Mfg. Co., Inc.
Minneapolis-Honeywell Regulator Co.
Permutit Co.
Philadelphia Gear Works, Inc.
Henry Pratt Co.
Rockwell Mfg. Co.
S. Morgan Smith Co.
Taller & Cooper, Inc.
Walker Process Equip., Inc.

VALVES, WATER METER SPECIAL
Ford Meter Box Co., Inc.
Hersey Mfg. Co.
Mueller Co.
Sparling Meter Co., Inc.
Taller & Cooper, Inc.

VARIABLE SPEED TRANSMISSIONS
Allis-Chalmers Mfg. Co.
Electric Machinery Mfg. Co.
Link-Belt Co.
Philadelphia Gear Works, Inc.
U. S. Electrical Motors, Inc.
Worthington Corp.

VENTURI TUBES
Bailey Meter Co.
Builders-Providence, Inc.
Fischer & Porter Co.
Foxboro Co.
Infilco, Inc.
F. B. Leopold Co., Inc.
Simplex Valve & Meter Co.
Taller & Cooper, Inc.

VIBRATING SCREENS (Liquid)
Link-Belt Co.

VITRIFIED CLAY PIPE AND PRODUCTS
American Vitrified Products Co.
Natco Corp.
National Clay Pipe Mfrs., Inc.

WASTE GAS BURNERS
Pacific Flush Tank Co.

WATER ANALYSIS EQUIPMENT AND REAGENTS
(See Laboratory Apparatus & Reagents)

WATER LEAK, LOCATING INSTRUMENTS
Computer-Measurements Corp.
W. S. Darley & Co.
Joseph G. Pollard Co., Inc.
Simplex Valve & Meter Co.
Wilkinson Products Co.

WATER LEVEL CONTROL
Bailey Meter Co.
Builders-Providence, Inc.
Control Corp.
Fischer & Porter Co.
Foster Engineering Co.
Foxboro Co.
General Electric Co.
Healy-Ruff Co.
Infilco, Inc.
Leupold & Stevens Instruments, Inc.
Minneapolis-Honeywell Regulator Co.
Simplex Valve & Meter Co.
Smith & Loveless, Inc.
S. Morgan Smith Co.
Sparling Meter Co., Inc.
Taller & Cooper, Inc.

WATER LEVEL RECORDERS
Bailey Meter Co.
Builders-Providence, Inc.
Control Corp.
Fischer & Porter Co.
Foster Engineering Co.
Foxboro Co.
General Electric Co.
Infilco, Inc.
Leupold & Stevens Instruments, Inc.
Minneapolis-Honeywell Regulator Co.
Simplex Valve & Meter Co.
Sparling Meter Co., Inc.
Taller & Cooper, Inc.
Wallace & Tiernan, Inc.

WATER MAIN CLEANING
Flexible Pipe Cleaning Co.
Flexible Inc.
National Water Main Cleaning Co.

WATERPROOFING PAINTS, COMPOUNDS AND MATERIALS
Johns-Manville
Koppers Co., Inc.
J. W. Mortell Co.
Pittsburgh Coke & Chemical Co.
Presstite-Keystone Engr. Products Co.
Standard Dry Wall Products, Inc.
U. S. Rubber Co.

WATER SOFTENING CHEMICALS AND COMPOUNDS
(See Individual Chemicals for Water Purification and Softening)

WATER SOFTENING EQUIPMENT
Allis-Chalmers Mfg. Co.
American Water Softener Co., Inc.
American Well Works
Chemical Equipment Co.
Dorr-Oliver, Inc.
General Filter Co.
Graver Water Conditioning Co.
Infilco, Inc.
Lakeside Engr. Corp.
Layne & Bowler, Inc.
F. B. Leopold Co., Inc.
Modern Swimming Pool Co., Inc.
Omega Machine Co.
Permutit Co.
Proportioneers, Inc.
Roberts Filter Mfg. Co.
Stuart Corp.
Walker Process Equip., Inc.

WATER SUPPLY CONTRACTORS
(See Contractors)

WATER TREATMENT FOR SCALE AND CORROSION
Allis-Chalmers Mfg. Co.
American Water Softener Co., Inc.
American Well Works
Calgon, Inc.
Chemical Equipment Co.
General Filter Co.
Graver Water Conditioning Co.
Infilco, Inc.
John Wiley Jones Co.
Lakeside Engr. Corp.
Olin Mathieson Chemical Corp.
Omega Machine Co.
Permutit Co.
Proportioneers, Inc.
Wallace & Tiernan, Inc.

WEED KILLERS
Columbia-Southern Chemical Corp.
Diamond Alkali Co.
General Chemical Div.
Koppers Company, Inc.
Pennsalt of Washington
U. S. Rubber Co.

WELL CLEANING CHEMICALS
Calgon, Inc.
General Chemical Div.
Layne & Bowler, Inc.
Olin Mathieson Chemical Corp.
U. S. Rubber Co.

WELLS, COMPLETE
Layne & Bowler, Inc.
Ranney Method Water Supplies, Inc.

WRAPPING, PIPE
(See Pipe, Wrapping)

ZEOLITE AND ZEOLITE SOFTENERS
Allis-Chalmers Mfg. Co.
American Water Softener Co., Inc.
Chemical Equipment Co.
General Filter Co.
Graver Water Conditioning Co.
Infilco, Inc.
Lakeside Engr. Corp.
Permutit Co.
Roberts Filter Mfg. Co.

DIRECTORY OF MANUFACTURERS

Listed in Classified Index of Products

A

ACF Industries, Inc.
P. O. Box 2117,
Houston, Texas

Airkem, Inc.
241 E. 44th St.
New York 17, N. Y.

Alabama Pipe Co.
P. O. Box 791
Anniston, Ala.

Alco Products Inc.
Schenectady 5, N. Y.

Allis-Chalmers Mfg. Co.
1192 S. 70th St.,
Milwaukee 1, Wis.

Amercoat Corporation
4809 Firestone Blvd.
South Gate, Calif.

American Cast Iron Pipe Co.
P. O. Box 2603,
Birmingham 2, Ala.

Amer. Concrete Pipe Assn.
228 N. LaSalle St.
Chicago 1, Ill.

American Concrete Pressure Pipe Assoc.
228 N. LaSalle St.
Chicago 1, Ill.

American Hard Rubber Co.
93 Worth St.
New York 13, N. Y.

American Vitrified Products Co.
701 National City Bank Bldg.
Cleveland 14, Ohio

American Water Softener Company
Lehigh and 4th Streets
Philadelphia, Pa.

American Well Works Co.
100 N. Broadway
Aurora, Ill.

Anthracite Equipment Co.
Anthracite Institute Bldg.
Wilkes Barre, Pa.

Aurora Pump Div.,
New York Air Brake Co.,
68 Loucks St.
Aurora, Ill.

B

Badger Meter Mfg. Co.
2371 N. 30th St.
Milwaukee, Wis.

Bailey Meter Mfg. Co.
1072 Ivanhoe Road
Cleveland, Ohio

Beaumont Birch Co.
1505 Race St.
Philadelphia 2, Pa.

A. O. Beckman Co.
1020 Mission St.
South Pasadena 19, Calif.

Beckman Instruments Inc.
Scientific Instruments Div.
2500 Fullerton Rd.,
Fullerton, Calif.

Ernest Bernard Elec. Co.
10335 S. Morgan St.
Chicago 43, Ill.

Bethlehem Steel Co.
E. 3rd St.
Bethlehem, Pa.

B-I-F Industries, Inc.
345 Harris Ave.
Providence, R. I.

Blackburn-Smith Manufacturing Co.
150 Observer Highway
Hoboken, N. J.

Borden Metal Products Co.
866 Green Lane,
Union, N. J.

Bucyrus-Erie Co.
Publicity Dept.
S. Milwaukee, Wis.

Buffalo Meter Co.
2914 Main St.
Buffalo 14, N. Y.

Builders-Providence, Inc.
Div. of B-I-F Industries Inc
345 Harris Ave.
Providence, R. I.

A. M. Byers Co.
Clark Bldg.
Pittsburgh 22, Pa.

Byron Jackson Div.,
Borg-Warner Corp.
Box 2017, Terminal Annex
Los Angeles 54, Calif.

C

Calgon, Inc.
Hagan Bldg.
Pittsburgh, Pa.

Carborundum Co.
Perth Amboy, N. J.

Cast Iron Pipe Research Assn.
122 South Michigan Ave.
Chicago 3, Ill.

Cement Gun Co.
1505 Walnut St.
Allentown, Pa.

Centriline Corp.
140 Cedar St.
New York 6, N. Y.

Chain Belt Co.
4610 W. Greenfield Ave.
Milwaukee 1, Wis.

Champion Corp.
4718 Sheffield
Hammond, Ind.

Chapman Valve Mfg. Co.
Indian Orchard, Mass.

Chemical Equipment Co.
P. O. Box 3098, Terminal Annex
Los Angeles 54, Calif.

Chemical Fire & Rust Proofing Corp.
50 Cutter Mill Rd.
Great Neck, N. Y.

Chicago Bridge & Iron Co.
332 S. Michigan Ave.
Chicago 4, Ill.

Chicago Pump Company
622 Diversey Pkway
Chicago 14, Ill.

H. W. Clark Company
Mattoon, Ill.

Cleveland Trencher Co.
20100 St. Clair Ave.
Cleveland 17, Ohio

Climax Engine & Pump Mfg. Co.
208 S. LaSalle St.
Chicago 4, Ill.

James B. Clow & Son
201 N. Talman Ave.
Chicago 80, Ill.

R. D. Cole Mfg. Co.
Newnan, Ga.

Colonial Plastics Mfg. Co.,
2685 E. 79th St.,
Cleveland 4, Ohio

Columbia-Southern Chemical Corp.
Subsidiary of Pittsburgh Plate Glass Co.
Pittsburgh 22, Pa.
(1 Gateway Center)

Combustion Engineering, Inc.
200 Madison Ave.
New York, N. Y.

Computer-Measurements Corp.
5528 Vineland
North Hollywood, Calif.

Consolidated Chemical Industries
Div. of Stauffer Chemical Co.
640 Esperson Building
Houston 2, Texas

Continental Can Co.
Mills Plastic Pipe Division
100 E. 42nd St.
New York 17, N. Y.

Continental Steel Corp.
Chain Link Fence Div.
Kokomo, Ind.

Control Corp.
718 Central Ave.
Minneapolis, Minn.

Cook Well Strainer Co.
3264 Beekman
Cincinnati 23, Ohio

Crane Co.
836 S. Michigan Ave.
Chicago, Ill.

D

W. S. Darley & Co.
2810 Washington Blvd.
Chicago, Ill.

Darling Valve & Mfg. Co.
Ft. of Walnut St.
Williamsport 28, Pa.

DeLaval Steam Turbine Co
824 Nottingham Way,
Trenton, N. J.

DeZurik Shower Co.
Sartell, Minn.

Diamond Alkali Co.
300 Union Commerce Bldg
Cleveland 14, Ohio

Dorr-Oliver Corp.
Barry Place
Stamford, Conn.

Dresser Mfg. Div.,
Dresser Industries, Inc.
59 Fisher Ave.
Bradford, Pa.

E

Economy Pumps Inc., Div. C. H. Wheeler Mfg. Co.,
19th and Lehigh
Philadelphia 32, Pa.

The Eddy Valve Company
Waterford, N. Y.

Electric Machinery Mfg. Co.
800 Central Ave.
Minneapolis 13, Minn.

Electro Rust Proofing Corp.
1 Main St.
Belleville 9, N. J.

Ellis & Ford Mfg. Co., Inc.
2423 Goodrich Ave.
Ferndale 20, Mich.

Everson Mfg. Company
214 W. Huron St.
Chicago 10, Ill.

F

Fairbanks Morse & Co.
600 S. Michigan Ave.
Chicago, Ill.

Filer & Stowell Co.
147 East Becher St.
Milwaukee, Wis.

Filtration Equipment Corp.
271 Hollenbeck St.
Rochester 21, N. Y.

Filtros Inc.
East Rochester, N. Y.

Fine Organics Inc.
211 East 19th St.
New York 10, N. Y.

Fischer & Porter Co.
925 Warminster Rd.
Hatboro, Pa.

Flexible Inc.
3786 Durango Ave.
Los Angeles 34, Calif.

Flexible Pipe Cleaning Co.
9324 So. Norwalk Blvd.
Los Nietos, Calif.

Ford Meter Box Co., Inc.
Wabash, Ind.

Foster Engineering Co.
835 Lehigh Ave.
Union, N. J.

Foxboro Corp.
85 Neponset Ave.
Foxboro, Mass.

Frontier Chemical Co., Div. of Union Chemical & Materials Corp.
Wichita, Kansas

G

General Chemical Div.
Allied Chemical & Dye Corp
40 Rector St.
New York 6, N. Y.

General Electric Company
One River Road
Schenectady, N. Y.

General Filter Co.
923 2nd St.
Ames, Iowa

Glenfield & Kennedy Inc.
706 North Ave.
New Rochelle, N. Y.

Golden-Anderson Valve Specialty Co
1232 Ridge Ave.
Pittsburgh 33, Pa.

Graver Water Conditioning Co.
216 W. 14th St.
New York 11, N. Y.

Grinnell Company, Inc.
270 W. Exchange St.
Providence, R. I.

Gruendler Crusher & Pulverizer Co.
2915-2917 No. Market
St. Louis 6, Mo.

H

Hagan Corporation
Hagan Building
Pittsburgh 30, Pa.

Hamilton Kent Mfg. Co.
427 West Grant St.
Kent, Ohio

Hammarlund Mfg. Co., Inc.
460 West 34th St.
New York 1, N. Y.

Hammond Iron Works
630 Fifth Ave.
New York 20, N. Y.

Hardinge Co.
240 Arch St.
York, Pa.

Healy-Ruff Company
2255 University Ave.
St. Paul 14, Minn.

Hercules Powder Co.
Wilmington 99, Del.

Hersey Mfg. Co.
Cor. E. & 2nd Sts.
S. Boston, Mass.

Hollaender Mfg. Co.
3834 Spring Grove Ave.
Cincinnati 23, Ohio

Homelite Div., of Textron American Inc.
P. O. Box 150
Port Chester, N. Y.

Homestead Valve Mfg. Co.
Box 42
Coraopolis, Pa.

Hydraulic Development Co
50 Church St.
New York, N. Y.

I

Infilco Incorporated
901 S. Campbell Ave.
Tucson, Ariz.

International Minerals & Chemical Corp.
20 N. Wacker Dr.
Chicago 6, Ill.

Iowa Valve Co.
201 No. Talman Ave
P. O. Box 6600-A
Chicago 80, Ill.

J

Jeffrey Mfg. Co.
996 No. Fourth St.
Columbus 16, Ohio

Johns-Manville Corp.
22 E. 40th St.
New York 16, N. Y.

Edward E. Johnson, Inc.
315 N. Pierce St.
St. Paul 4, Minn.

Johnston Pump Co.
Pasadena 15, Calif.

John Wiley Jones Co.
Caledonia, N. Y.

K

Keasbey & Mattison Co.
Butler Ave.
Ambler, Pa.

Klett Mfg. Company
179 E. 87th St.
New York 28, N. Y.

Komline Sanderson Eng. Corp.
Peapack, N. J.

Koppers Co.
Koppers Bldg.
Pittsburgh 19, Pa.

L

Lakeside Engr. Corp.
222 West Adams St.
Chicago, Ill.

Layne & Bowler, Inc.
Box 6697, Hollywood Sta.,
Memphis 8, Tenn.

F. B. Leopold Co., Inc.
2413 W. Carson St.
Pittsburgh, Pa.

Le Roi Div. Westinghouse Air Brake Co.
1706 South 68th St.
Milwaukee 1, Wis.

Leupold & Stevens Instruments Inc.
4445 N. E. Glisan
Portland 13, Oregon

Link-Belt Co.
Colmar, Pa.

Lock Joint Pipe Co.
Box 269
E. Orange, N. J.

Ludlow Valve Mfg. Co.
P. O. Box 388
Troy, N. Y.

M

M. & H. Valve & Fittings Co.
Anniston, Ala.

M-C-G Co.
1771 W. 5th Ave.
Columbus 12, Ohio

Millipore Filter Corp.
36 Pleasant St.
Watertown 72, Mass.

Minneapolis-Honeywell Regulator Co.
Industrial Division
Wayne & Windrim Aves.
Philadelphia 44, Pa.

Modern Swimming Pool Co., Inc.
One Holland Ave.,
White Plains, N. Y.

Morse Boulger Destructor Co.
80 Fifth Ave., New York, N. Y.

Morse Bros. Machinery
Denver, Colo.

J. W. Mortell Co.
550 N. Hobbie Ave.
Kankakee, Ill.

Mueller Co.
512 W. Cerro Gordo
Decatur 8, Ill.

Multiplex Mfg. Co.
Berwick, Pa.

N

Natco Corp.
327 5th Ave.
Pittsburgh 22, Pa.

National Clay Pipe Mfrs. Inc
1520 18th St. N. W.
Washington 6, D. C.

National Power Rodding Corp
1000 S. Western Ave.
Chicago 12, Ill.

National Water Main Cleaning
50 Church St.
New York 7, N. Y.

Neptune Meter Co.
19 West 50th St.
New York 20, N. Y.

Niagara Alkali Co.
60 E. 42nd St.
New York, N. Y.

Nooter Corporation
1480 South Second St.
St. Louis 4, Mo.

Norwalk Valve Co.
230 Park Ave.,
New York, N. Y.

O

Olin Mathieson Chemical Corp.
Indus. Chem. Div.
Mathieson Bldg.
Baltimore 3, Md.

The Oliver Corp. Industrial Division
400 W. Madison
Chicago 6, Ill.

Omega Machine Co., Div. of B-I-F Industries Inc.
345 Harris Ave.
Providence, R. I.

P

Pacific Flush Tank Company
4141 Ravenswood Ave.
Chicago 13, Ill.

Payne Dean & Co.
Clinton, Conn.

Penn Salt Mfg. Co.
3 Penn Center Plaza
Philadelphia 2, Pa.

Pennsalt Mfg. Co. of Washington
2901 Taylor Way, Tacoma, Wash.

Peerless Pump Div., Food Machinery & Chemical Corp.
301 W. Ave. 26
Los Angeles 31, Calif.

Permutit Co.
330 West 42nd St.
New York, N. Y.

Phelps Dodge Refining Corp.
300 Park Ave., New York 22, N. Y.

Philadelphia Gear Works Inc.
"G" St. below Erie Ave.
Philadelphia 34, Pa.

Philadelphia Quartz Company
Public Ledger Bldg.
Philadelphia 6, Pa.

Phipps & Bird Company
6th & Byrd Sts.
Richmond 5, Va.

Pittsburgh Coke & Chemical Co.
Grant Bldg.
Pittsburgh, Pa.

Pittsburgh-Des Moines Steel Co.
3418 Neville Island
Pittsburgh, Pa.

Jos. G. Pollard Co., Inc.
New Hyde Park, N. Y.

Portland Cement Association
33 W. Grand Ave.
Chicago, Ill.

Henry Pratt Co., Inc.
2222 S. Halsted St.,
Chicago 8, Illinois

The Preload Co., Inc.
211 E. 37th St.
New York 16, N. Y.

Prescott Tool Co., Inc.
Box 7 Greendale Branch
Worcester 6, Mass.

Presstite-Keystone Engr. Products Co.
Div. of American Marietta Co.
3798 Chouteau Ave.
St. Louis 10, Mo.

Price Brothers Co.
1932 East Monument Ave.
Dayton 1, Ohio

Proportioneers, Inc. Div. of B-I-F Industries Inc.
345 Harris Ave.
Providence 1, R. I.

R

Ranney Method Water Supplies, Inc.
Box 5415, Shepard Sta.
Columbus 19, Ohio

Reliance Chemicals Corp.
P. O. Box 6724
Houston 5, Texas

Rensselaer Valve Div., Ludlow Valve Mfg Co., Inc.
Troy, N. Y.

Roberts Filter Mfg. Co.
607 Columbia Ave.
Darby, Pa.

Rockwell Mfg. Co.
400 N. Lexington Ave.
Pittsburgh, Pa.

W. S. Rockwell Co.
200 Eliot St.
Fairfield, Conn.

Roots-Connersville Blower Div. of Dresser Industries, Inc.
900 West Mount St.
Connersville, Ind.

Royer Foundry & Machine Co.
170 Pringle St.
Kingston, Pa.

S

Safety Gas Main Stopper Co., Inc.
523 Atlantic Ave.
Brooklyn 17, N. Y.

Schramm Inc.
Westchester, Pa.

Simplex Valve Meter Co.
7 East Orange St.
Lancaster, Pa.

M. B. Skinner Co.
3502 W. Sample St.
South Bend, Ind.

A. P. Smith Mfg. Co.
545 N. Arlington Ave.
East Orange, N. J.

S. Morgan Smith Co.
500 Lincoln St.
York, Pa.

Smith & Loveless, Inc.
P. O. Box 8172
Kansas City, Mo.

Sparling Meter Co.
945 No. Main St.
Los Angeles, Calif.

Speelman Elevated Tank Service
822 N. Court St.
Rockford, Ill.

Spring Load Mfg. Co.
3610 First Ave. South
Seattle, Wash.

Standard Dry Wall Products
Box X
New Eagle, Pa.

Stuart Corp.
516 N. Charles St.
Baltimore 1, Md.

T

Taller & Cooper, Inc.
75 Front St., Brooklyn 1, N. Y.

W. A. Taylor & Co.
7300 York Road
Baltimore 4, Md.

Tennessee Corporation
619 Grant Bldg.
Atlanta 1, Ga.

U

U. S. Electrical Motors, Inc
200 E. Slauson Ave.
Los Angeles 54, Calif.

U. S. Pipe & Foundry Co.
3300 First Ave. North
Birmingham, Ala.

U. S. Rubber Co.
1230 6th Ave.
New York, N. Y.

W

Walker Process Equipment Inc
P. O. Box 266
Aurora, Ill.

Wallace & Tiernan
25 Main St.
Belleville 9, N. J.

Washington Aluminum Co. Inc
Knecht Ave. and Pennsylvania Railroad
Baltimore 29, Md.

Weil Pump Co.
1530 N. Fremont St.
Chicago 22, Ill.

Weinman Pump Mfg. Co.
286 Spruce St.
Columbus, Ohio

Western Machinery Co.
760 Folsom St.
San Francisco 7, Calif.

Westinghouse Electric Corp.
Gateway Center
401 Liberty Ave.
Pittsburgh 30, Pa.

West Virginia Pulp and Paper Co.
Industrial Chemical Sales Div.
230 Park Ave.
New York 17, N. Y.

White Diesel Engine Div.
The White Motor Co.
1401 Sheridan
Springfield, Ohio

Wilkinson Products Co.
3987 Chevy Chase Dr.
Pasadena 3, Calif.

A. Reed Wilson Co.
1320 McGee St.
Kansas City 6, Mo.

W-K-M Mfg. Co., Inc.
ACF Industries, Inc.
P. O. Box 2117
Houston, Texas

R. D. Wood Company
Public Ledger Bldg.
Philadelphia 5, Pa.

Woodward Iron Company
Woodward, Ala.

Worthington Corp.
401 Worthington St.
Harrison, N. J.

Worthington Gamon Meter Div.
Worthington Corp.
296 South St.
Newark 5, N. J.

Y

Yeomans Brothers Co.
1999-9 N. Ruby St.
Melrose Pk., Ill.

Zimmer & Francescon
P. O. Box 359
Moline, Ill.

II. INTRODUCTION

The practice involved in the supplying of water to a municipality or disposing of its sewage have a number of fundamental factors in common. While it is true that there are many individual practices which differ in details, the many common fundamentals make water supply and sewage treatment one basic field.

Included in these common fundamentals are public health aspects, hydraulic laws, treatment processes, purpose of treatment, community problems, etc. Further than that, these fundamentals can be broken down to individual factors which have a common application to both water and sewage.

Management

Inasmuch as both water supply and sewage disposal are municipal operations, they are frequently subject to the same management. When one understands the factors involved in management, there is good cause to adopt combined management of water and sewage works operations.

Management involves a number of practices. These include financing, rate schedules, office operations, public relations and policies, lands and laws, personnel administration and safety.

Functional Operations

Certain operating procedures, functional in nature, are fundamental to both water supply and sewage disposal and treatment. These operations include pumping, electrical operations, measurement of flow, instrumentation and control, chemical handling and feeding, mixing, coagulation, flocculation, sedimentation, corrosion control, laboratory control and maintenance.

Also basic to both water supply and sewage treatment are the fundamental and applied sciences which are basic to both. These include physics, chemistry, bacteriology, other biological sciences, hydraulics and of course, mathematics. Of particular interest are bacteriology, chemistry and hydraulics.

Two other factors are common to water supply and sewage disposal. These are design and construction. Inasmuch as both water and sewage are transported in pipes or conduits and are treated in tanks or filters, it is to be expected that design problems will be subject to the same type of engineering solution. Pumps, motors, instruments, controls, equipment, etc. are practically the same for water or sewage treatment plants. Construction of facilities, pipe and sewer laying, and so forth, utilize the same techniques and equipment for both water or sewage works.

Water Works Practice

A most important factor in water supply practice is the choice of supply source. All water supply originates in precipitation from the skies, but its storage on earth may be on the surface or underground. Surface supplies may be lakes, streams, impounded reservoirs or even springs. Ground water supplies include wells, of various depths, infiltration galleries and springs.

Transportation of water from source to treatment plant or to the distribution system takes place in transmission mains, conduits, or aqueducts. Distribution systems to carry the water to the ultimate consumer consist of large arterial mains, smaller secondary or distributor mains, minor distributors, and appurtenances including valves, hydrants and meters.

Treatment of water supply depends on the source and the amount and kind of impurities present. Ground waters are usually clear, cool and free of bacteria. If desired, it may be treated to remove hardness, iron and manganese. Chlorination as a safety measure is common. Surface waters generally need chemical treatment, with coagulation, flocculation and sedimentation, prior to filtration through sand. If tastes and odors are present they can be removed by aeration, chlorination or activated carbon treatment. Chlorination for disinfection is almost always used.

In some communities, fluoride compounds are added in extremely low concentrations (1ppm) to aid in the prevention of tooth decay. Control of corrosion is accomplished by neutralization and pH adjustment or the use of glassy phosphates.

Sewage Works Practice

Whereas a distribution system carries water to a consumer, a sewer system carries it away. House connections lead to lateral sewers, which connect with main or trunk sewers, which in turn join interceptors which lead to the treatment works.

Treatment of sewage has its purpose to protect public health and prevent nuisance conditions. Treatment is divided into four parts: Primary treatment, secondary treatment, disinfection, and solids disposal. Primary treatment involves screening and sedimentation to remove particulate matter. Secondary treatment utilizes bacteria and other microorganisms to oxidize organic matter, either by passing liquid over a surface as in a trickling filter, or by blowing air through the liquid containing active and growing microorganisms as in the activated sludge process.

Disinfection to destroy disease producing organisms is usually accomplished by chlorination. Disposal of the solids removed from sewage usually involves digestion or decomposition by bacteria in the absence of oxygen. This digested sludge is subjected to dewatering and drying processes, either natural or chemical and mechanical before final disposal as fill or for use as a soil conditioner. Sludge may be burned and the ash used for fill. Undigested sludge may be dewatered, dried and burned as a means of disposal.

Industrial Waste Treatment

Many wastes from industry are similar in nature to the organic matter in sewage and may therefore be treated with municipal wastes. Other industrial wastes require special treatment and are best handled by the industry itself. In any event the problem of industrial wastes within a community is of interest to the municipal sewage plant manager.

Inasmuch as the treatments and practice in both water and sewage treatments and practice in both water and sewage treatment involve so many factors and fundamentals, it behoves every plant manager, operators to have a good library. A suggested list of books follows in this issue.

BUILDERS

Meters and controls engineered specifically for water, sewage, and waste plants . . . proven in thousands of installations.

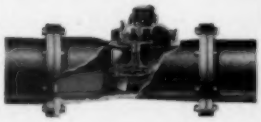
METERS

TYPE M INSTRUMENT

Type M Totalizer-Indicator-Recorder . . . extra-durable wide range instrument. Also smaller model Flo-Watch available. For use with Venturi tubes, nozzles, flumes, and weirs. Bulletin 200-H4A.

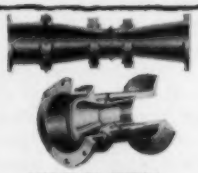
CHRONOFLO ELECTRIC TELEMETERS

Chronoflo Telemeters bring to central operating point records of flow, liquid level, etc. Connection is by simple two-wire circuit. Ideal for automatic proportional pacing of chemical feeders. Bulletin 230-H4.



PROPELOFLO METER

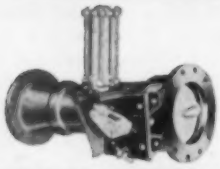
Propeller-type main line meter. Self-contained, easily installed. Can be used with indicating and recording secondary instruments, and to pace chemical feeders. Bulletin 380-K4.



VENTURI TUBES AND NOZZLES — DALL FLOW TUBE

Widest range of sizes and models for water, sewage, and waste flows: Venturi Tubes, Model NZIF Insert Nozzles, Model DFT Dall Flow Tubes, Kennison Nozzles. Write for recommendations.

CONTROLS



FILTER RATE CONTROLLERS

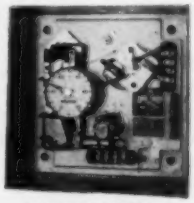
Direct-acting Model RCE and hydraulically powered Models RCB and RCB-T types. Their high and enduring accuracy have won acceptance of leading consulting engineers and plant operators. Rugged, simple construction for easy installation, operation, and maintenance. RCB-T is rubber seated, tight closing — no need for separate shutoff valve. Bulletins 600-G6, 600-J9A.

FILTER OPERATING TABLES & GAUGES

Attractive and convenient tables and gauges for centralized filter control. Gauges available for indicating and/or recording all operations. Tables have shift-type levers and piston-type four-way valves, plus valve position indicators. Bulletins 450-H10A, 470-E1B.

AUTO-CENTRAL FILTER CONTROLS

Reduce operating costs with complete remote control of filter effluent rates and valve operations, including automatic washing cycle — from a conveniently located Builders Auto-Central Control panel. Write for details.



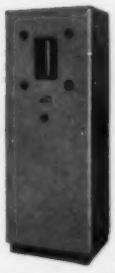
PUMP CONTROLS

More uniform system pressure . . . lower costs . . . with automatic Pressureflo Control for pumping stations; operates in response to both pressure and flow. Also Chronoflo Control for reservoir or elevated storage level control. Write for details.

CHLORINIZERS

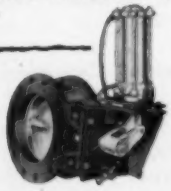
Three Models for chlorinating rates from 0 to 7500 lbs. per 24 hrs. Accurately meter chlorine gas and deliver a uniform chlorine water solution to point of application. Features include visible flow, rugged construction, simple design, and automatic safety devices of latest and most positive type. Easily modified to program, automatic-proporational, or sequence control.

Model CVS
Chlorinizer
Bulletin 840-K18
840-J308, 840-J84



SYNCHRO-SCAN SUPERVISORY CONTROL

Any number of plant operating functions — pumps, valves, tank levels, etc. — can be controlled or monitored from central panel. Uses simple two-wire transmission or leased telephone circuit. Plug-in components for easy inspection and servicing. Bulletin 240-M6.



BUTTERFLY VALVES

Built to AWWA Specifications — highest quality design, sturdy construction, durable materials throughout. Rubber-seated, tight-closing. Furnished with manual, pneumatic, hydraulic, or electric motor operators. Backed by our nationwide sales and service organizations. Bulletin 650-L1B.

For Bulletins on individual products or for comprehensive Bulletin B-I-F 6, write **Builders-Providence, Inc.**, 376 Harris Avenue, Providence 1, R. I., . . . division of

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FEEDERS
CONTROLS

BUILDERS-PROVIDENCE, INC. • OMEGA MACHINE CO. • PROPORTIONEERS, INC.

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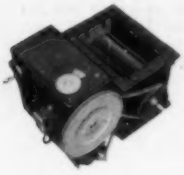
You can depend on Omega for "the last word in feeders" . . . and the answer to your chemical feeding problem . . . always!

BELT TYPE GRAVIMETRIC
Three models for feeding materials by weight continuously on short conveyor belt carried on sensitive scales. High accuracy — wide range — from a few cu. ins./min. to 100,000 lbs./hr. Bulletins 35-J11, H5.

LOSS-IN-WEIGHT TYPE
Finest weighing type feeders for super-accurate chemical feeding. Adjustable in pounds per hour over 100 to 1 range. Three models (maximums of 100, 1000, and 4000 lbs./hr.). Bulletins 30-H12, K4.

UNIVERSAL FEEDERS
Handles dry material dependably and accurately . . . whether lumps or fine powder, light or heavy. Large throat openings, effective agitation at the outlet zone. 40 to 1 range. Furnished in 3 sizes. Bulletin 20.20.

VOLUMETRIC FLUORIDIZER
Model 50 Fluoridizer provides highly accurate, wide range fluoridation at a cost within the means of small plant budgets. Rugged — compact — low filling height — dustless loading. Bulletin 50-K3.



ROTOLOCK FEEDERS
Non-flooding, especially suitable for feeding fine, dry materials. Omega variable speed transmission permits infinite adjustment over 100 to 1 range. Three styles of rotors. Bulletin 45.20.

LIME SLAKERS
Lime Slakers . . . continuous operation . . . available with capacities from 50 lbs./hr. to 10,000 lbs./hr. Rapid, thorough slaking . . . maintains high slaking temperature. Furnished with Gravimetric or Volumetric Feeders. Bulletin 40.20.

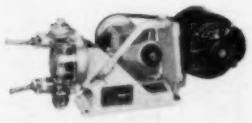
ROTODIP FEEDERS
Rotodip Feeders for feeding and metering low viscosity liquids and suspensions by volume. 100 to 1 range. Capacities to 1800 GPH (special models for higher rates).

BUCKET ELEVATOR
Ideal for use where large hopper capacity is required and the hopper must be loaded from the same floor on which the feeder is located. Send for bulletin which shows diagram of a complete installation with accessories. Bulletin 77-J7.

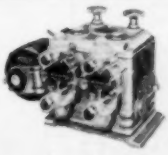
Write for Bulletins on individual products, or comprehensive Bulletin B-I-F 6 . . . also Bulletin 10—K12A "Chemicals Used in Water & Sewage Treatment". Omega Machine Co., 376 Harris Ave., Providence 1, R. I.

Proportioneers

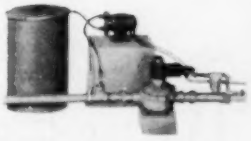
Largest manufacturer of chemical proportioning equipment . . . service-proven in over 40,000 installations.



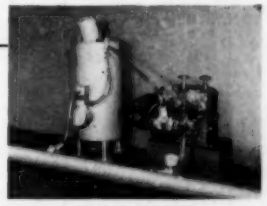
HEAVY DUTY MIDGET
All-purpose, positive displacement, diaphragm pump feeds safely and dependably a variety of corrosive fluids: hypochlorite, pH correctives, anti-corrosion chemicals — also abrasive slurries. Cap. 0.5 to 9 GPH against pressures to 85 psig. Comes as "package" for easy installation and operation. Bulletin 1201-2.



CHEM-O-FEEDER®
Deluxe chemical proportioning pump for caustics, acids, slurries, etc. Features feed rate adjustment while in operation. Simplex, duplex (shown), and triplex models — feed rates 0.2 to 57 GPH for discharge pressures to 125 psig. "See-thru" reagent end gives visual check on pump operation. Bulletin 1225-1.



AUTOMATIC/PROPORTIONAL CHEM-O-FEEDER
Powered by the flow through the pipe line, this efficient feeder controls chemical feed in proportion to main line flow. Paced by standard main line, bypass, or fire line meters. Capacities 0 to 5 GPH against 4 to 100 psig. pressures. Bulletin 1260-2.



FLUSH FEEDER
(Patent Applied For)
For controlled feeding of slurries of thin mudlike consistency or corrosive chemicals. Unique check valve assembly mounted directly on slurry tank handles slurry . . . metering pump handles nothing but flushing fluid. Provides positive slurry flows. Reduces need for frequent slurry make-up and reduces tank costs. Send for details.

Send for product Bulletins, or comprehensive Bulletin B-I-F 6. Proportioneers, Inc., 376 Harris Ave., Providence 1, R. I.

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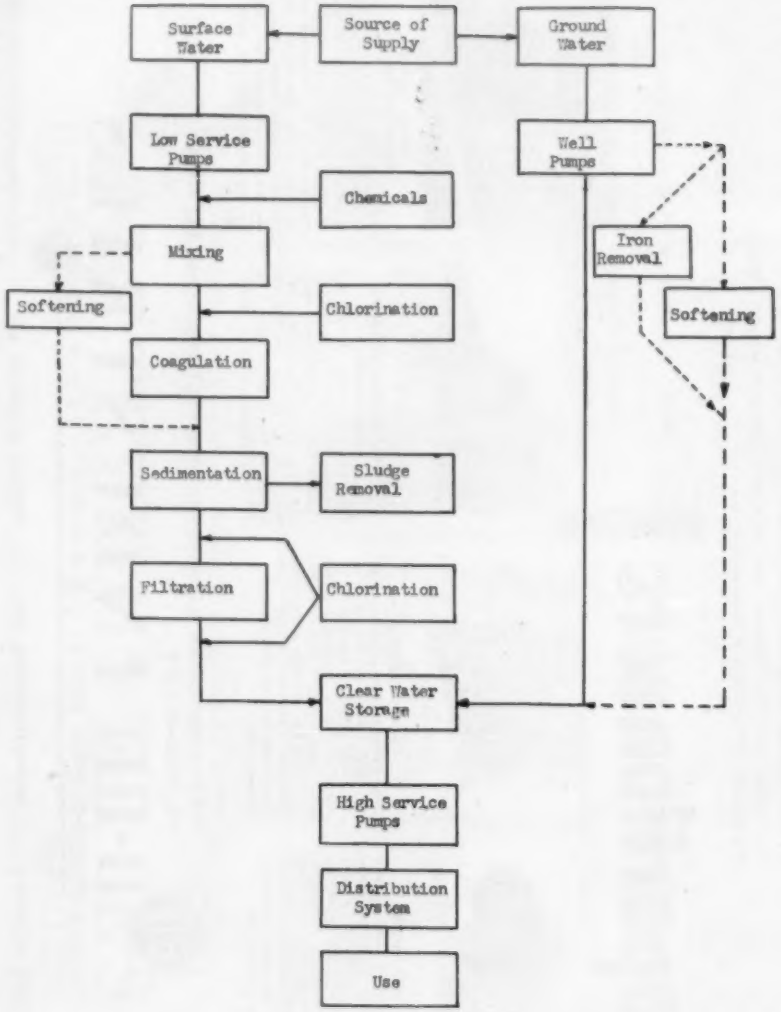
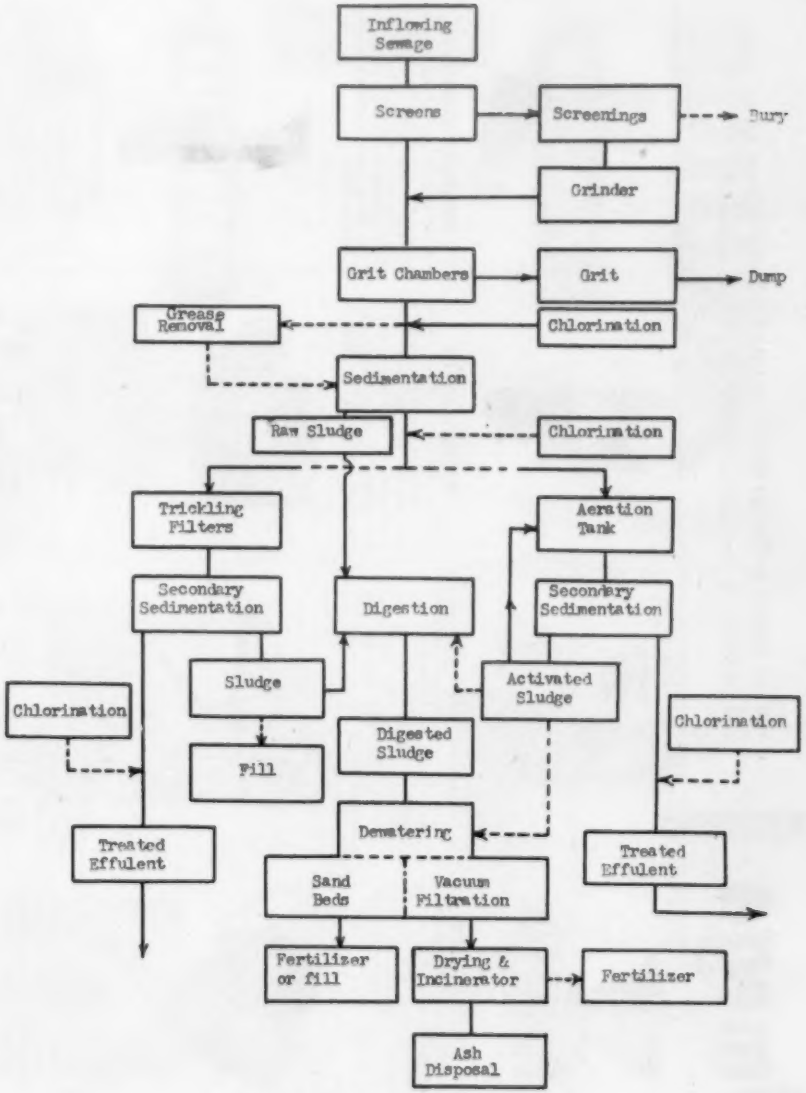
BUILDERS IRON FOUNDRY • PROPORTIONEERS, INC. • OMEGA MACHINE CO. • BUILDERS-PROVIDENCE, INC.



FLOW diagram of water supply system



FLOW diagram of sewage treatment works

Books and Reference Manuals

Suggested Library Material for Water and Sewage Works

by LINN H. ENSLOW and GEORGE E. SYMONS, Ph. D.

Co-Editors, Reference & Data Number, Water & Sewage Works

Title and Price (F=Free)	*Publisher*	*Author*

I. Books for All Water and Sewage Works

First Aid, 4th Ed.	Appleton-Century-Crofts, Inc.	Cole and Puestow
Glossary—Water and Sewage Control Engineering ($1.00)	ASCE, APHA, AWWA, FSIWA	
Laboratory Manual for Water & Sewage Analysis, 3rd Ed. ($4.50)	McGraw-Hill Book Co.	Theroux, Malmann & Eldridge
Lime Handling, Application and Storage in Treatment Processes (F)	National Lime Assn.	Rudolfs
Modern pH and Chlorine Control, 12th Ed. (F)	W. A. Taylor Co.	Taylor & McCrumb
Pipe Friction Manual, 1954 Ed. ($1.75)	Hydraulic Institute	
Rural Water Supply and Sanitation, 2nd Ed. ($4.90)	John Wiley & Sons	Wright
Standard Methods for the Examination of Water, Sewage, and Industrial Wastes, 10th Ed. ($7.50)	APHA, AWWA, & FSIWA	
Water Conditioning Data Book, 4th Ed. (F)	The Permutit Co.	

II. Books for Large Water and Sewage Works

American Civil Engineers' Handbook, 5th Ed. ($14.00)	John Wiley & Sons	Merriman & Wiggin
Civil Engineering Handbook, 3rd Ed. ($11.00)	McGraw-Hill Co.	Urquardt
Concrete Engineers Handbook	McGraw-Hill Book Co.	Hool and Johnson
Corrosion: Causes and Prevention, 3rd Ed. ($11.00)	McGraw-Hill Book Co.	Speller
Corrosion Handbook ($15.00)	John Wiley & Sons	Uhlig
Data Book for Civil Engineers, I—Design, 2nd Ed. ($16.75)	John Wiley & Sons	Seelye
Data Book for Civil Engineers, II—Specifications and Costs 2nd Ed. ($16.75)	John Wiley & Sons	Seelye
Data Book for Civil Engineers, III—Field Practice 2nd Ed. ($7.50)	John Wiley & Sons	Seelye
Engineering in Public Health ($9.00)	McGraw-Hill Book Co.	Babbitt
Freshwater Biology, 1918 Ed. ($10.75)	John Wiley & Sons	Ward & Whipple
Fundamental Considerations in Rates and Rate Structures for Water and Sewage Works—Joint Comm. Rept. ($1.00)	ASCE, ABA, AWWA, APHA, NARUC	
Handbook of Applied Hydraulics, 2nd Ed. ($15.00)	McGraw-Hill Book Co.	Davis
Handbook of Chemistry and Physics, 37th Ed. ($12.00)	Chemical Rubber Co.	
Handbook of Hydraulics, 5th Ed. ($8.00)	McGraw-Hill Book Co.	King
Hydraulic Tables 3rd Ed. ($4.50)	John Wiley & Sons	Williams & Hazen
Industrial Water & Industrial Waste Water Analysis, 1953 Ed. ($1.50)	Am. Soc. Test. Mtls.	
Introduction to the Bacteria ($6.50)	McGraw Hill Book Co.	Clifton
Mechanical Engineers' Handbook, Power Volume, 12th Ed. ($10.00)	John Wiley & Sons	Kent-Salisbury
Microbiology, 2nd Ed. ($7.50)	Appleton-Century-Crofts, Inc.	Kelly and Hite
Plane Surveying ($6.50)	John Wiley & Sons	Tracy
Practice of Sanitation ($8.00)	Williams & Wilkens Co.	Hopkins & Schulze
Public Health Engineering, Vol. I ($8.50)	John Wiley & Sons	Phelps
Public Health Engineering, Vol. II ($5.50)	John Wiley & Sons	Phelps
Pump Handbook ($4.00)	*The* National Press	Finch
Pumps ($6.50)	McGraw-Hill Book Co.	Kristal & Annett
Rainfall and Runoff ($9.00)	*The* Macmillan Co.	Foster
Specifications and Law on Engineering Works ($6.50)	John Wiley & Sons	Sadler
Standards of the Hydraulic Institute, 10th Ed. ($4.75)	Hydraulic Institute	
Standard Mathematical Tables, 10th Ed. ($3.00)	Chemical Rubber Co.	
Standard Practices for Low and Medium Speed Stationary Diesel Engines, 4th Ed. ($5.00)	Diesel Engine Mfrs. Assn.	
Treatise on Applied Hydraulics, 4th Ed. ($9.50)	John Wiley & Sons	Addison
Water Supply and Waste-Water Disposal ($15.00)	John Wiley & Sons	Fair & Geyer

III. Books for Small and Large Water Works

Fluoridation as a Public Health Measure ($4.50)	Am. Assn. for Advance of Science	Shaw, et al
Legal Guide for Water Works Men ($1.00)	Case-Shepperd-Mann Div., R.H.	Donnelly Co.
Manual for Water Plant Operators ($6.50)	Chemical Publishing Co.	Hirsch
Manual for Water Works Operators, 3rd Ed. ($5.00)	Tex. Wat. & Sew. Wks. Assn.	Billings, et al
Operation of Water Filtration Plants of Mechanical Gravity Type—Bul. No. 484 ($1.00)	San. Eng. Div., No. Car. St. Board of Health	
Taste and Odor Control in Water Purification, 2nd Ed. (F)	Industrial Chemical Sales Div.	

Title and Price (F=Free)	*Publisher*	*Author*
Water Purification Control, 3rd Ed. ($4.00)	Williams & Wilkins Co.	Hopkins
Water Supply and Treatment, 7th Ed. ($1.25)	National Lime Assn.	Hoover
Water Works Operation ($1.00)	Case-Shepperd-Mann Div., R. H. Donnelly Co.	
Water Works Questions and Answers ($1.00)	Case-Shepperd-Mann Div., R. H. Donnelly Co.	

IV. Books for Small and Large Sewage Works

Control of Sludge Quality ($1.00)	Case Shepperd-Mann Div., R. H. Connelly, Co.	
Controlling Roots in Sewers, Spec. Rept. No. 5 ($1.00)	Am. Pub. Wks. Assn.	
Handbook of Cast Iron Pipe, 2nd Ed. (F)	Cast Iron Pipe Research Assn.	
Laboratory Control of Sewage Treatment ($1.00)	Case-Shepperd-Mann Div., R. H. Donnelly, Co.	
Manual for Sewage Plant Operators, 2nd Ed. ($5.50)	Tex. Wat. & Sew. Wks. Assn.	Billings, et al
Practice of Sanitation ($8.00)	Williams & Wilkins	Hopkins & Schulze
Principles of Sewage Treatment, 4th Ed. ($1.25)	National Lime Assn.	Rudolfs
Recent Developments in Chlorination Practice, Spec. Rept. No. 9 ($1.00)	Am. Pub. Wks. Assn.	
Sewage Treatment ($6.75)	John Wiley & Sons	Imhoff & Fair
Sewage Works Guide ($1.00)	Case-Shepperd-Mann Div., R. H. Donnelly Co.	

V. Books for Large Water Works

Elements of Water Supply Engineering, 2nd Ed. ($5.00)	John Wiley & Sons	Waterman
Fresh Water Algae, 2nd Ed. ($11.00)	McGraw-Hill Book Co.	Smith
Ground Water ($9.00)	McGraw-Hill Book Co.	Tolman
Hydroelectric Handbook, 2nd Ed. ($16.00)	John Wiley & Sons	Creager & Justin
Hydrology ($7.50)	John Wiley & Sons	Wisler & Brater
Index to Proceedings & Journal AWWA—1881-1939 ($2.00)	Am. Wat. Wks. Assn.	
Laboratory Control of Water Purification ($4.00)	Case-Shepperd-Mann Div., R. H. Donnelly Co.	Cox
Manual of Water Works Accounting ($4.00)	Am. Wat. Wks. Assn.	
Manual on Industrial Water, 1954 Ed. ($5.00)	Am. Soc. Test. Mtls.	
Microscopy of Drinking Water, 4th Ed. ($12.00)	John Wiley & Sons	Whipple, Fair & Whipple
NPFA Handbook of Fire Protection, 11th Ed. ($10.50)	National Fire Protection Assn.	
Public Water Supplies, 4th Ed. ($7.00)	John Wiley & Sons	Turneaure & Russell
Survival and Retirement Experience with Water Works Facilities ($3.00)	Am. Wat. Wks. Assn.	
The Quest for Pure Water ($5.00)	Am. Wat. Wks. Assn.	N. M. Baker
Water Bacteriology, 6th Ed. ($5.25)	John Wiley & Sons	Prescott, Winslow & McCrady
Water Conditioning For Industry ($9.00)	McGraw-Hill Book Co.	Powell
Water Quality and Treatment, 2nd Ed. ($4.00)	Am. Wat. Wks. Assn.	
Water Supply and Purification, 3rd Ed. ($6.75)	International Textbook Co.	Hardenbergh
Water Supply Engineering, 5th Ed. ($8.50)	McGraw-Hill Book Co.	Babbitt & Doland
Water Supply and Sewerage, 3rd Ed. ($8.50)	McGraw-Hill Book Co.	Steel
Water Treatment and Purification, 2nd Ed. ($5.50)	McGraw-Hill Book Co.	Ryan
Water Treatment for Industrial and Other Uses ($12.00)	Reinhold Book Division	Nordell

VI. Books for Large Sewage Works

American Sewage Practice, Vol. II—Construction of Sewers ($9.00)	McGraw-Hill Book Co.	Metcalf & Eddy
American Sewage Practice—Vol. III—Disposal of Sewage, 3rd Ed. ($10.00)	McGraw-Hill Book Co.	Metcalf & Eddy
Industrial Waste Disposal Charges in Cities over 5000 Population, Spec. Rept. No. 185 ($2.00)	Am. Pub. Wks. Assn.	Baffa, et al
Industrial Wastes, Their Treatment and Disposal ($9.50)	Reinhold Book Div.	Rudolfs, et al
Industrial Waste Treatment ($7.50)	McGraw-Hill Book Co.	Besselievre
Principles of Industrial Waste Treatment ($9.50)	John Wiley & Sons	Gurnham
Recommended Minimum Requirements for Plumbing ($1.25)	U.S. Gov't Printing Office	
Sewerage and Sewage Disposal, 2nd Ed. ($8.50)	McGraw-Hill Book Co.	Metcalf & Eddy
Sewage Service Charges in Cities over 5000 Population Spec. Rept. No. 18 ($2.00)	Am. Pub. Wks. Assn.	Tatlock, et al
Sewerage and Sewage Treatment, 3rd Ed. ($6.75)	International Textbook Co.	Hardenbergh
Sewerage and Sewage Treatment, 7th Ed. ($8.75)	John Wiley & Sons	Babbitt
Stream Sanitation ($5.00)	John Wiley & Sons	Phelps
Twenty-Year Index to Sewage Works Journal (1920-48) ($4.50)	Fed. Sew. & Ind. Wastes Assns.	Wisely & Symons
Uniform System of Accounts for Sewer Utilities ($5.00)	Fed. Sew. & Ind. Wastes Assns.	

VII. Technical Reports, Manuals, Bulletins and Reprints[1]

A. Useful in Both Water and Sewage Works

Chemical Lime Facts (F)	National Lime Assn.	
Conversion Factors for Engineers, 23rd Ed. (F)	Dorr-Oliver, Inc.	

(1) The U. S. Public Health Service, all State Health Departments, and most colleges of engineering have many manuals, bulletins, and reprints (at nominal prices) of interest to water and sewage plant operation. Also, equipment manufactures offer free technical reprints on equipment and process operation in the fields of water supply and sewage disposal.

Title and Price (F=Free)	*Publisher*	*Author*
Financing Water Works and Sewerage Works Projects ($2.00)	Mo. Wat. & Sew. Conf.	Summers
Flow of Fluids Through Valves, Fittings and Pipe, 1956 Ed. (F)	Crane Co.	
Keep Sheets of B-I-F Industries, Inc. ($1.00)	B-I-F Industries, Inc.	
Manual on Chemical Feed Machines, 1953 Ed. ($2.00)	Mo. Wat. & Sew. Conf.	Schworm
Manual on Consumer Water Rates, Part 1, 1952 Ed. ($2.00)	Mo. Wat. & Sew. Conf.	Miller
Principles of Handling Chlorine (F)	*The* Chlorine Institute	Langworthy
Public Relations Manual for Water Works and Sewage Works Operators ($2.00)	Mo. Wat. & Sew. Conf.	Magill
Specifications for Stationary Chlorine Storage Installations (F)	*The* Chlorine Institute	
The Chlorine Manual (F)	*The* Chlorine Institute	

B. Useful in Water Works

Copper Sulfate in Control of Microscopic Organisms, 1954 Ed. (F)	Phelps Dodge Refining Corp.	Hale
Drinking Water Standards ($0.10)	Govt. Printing Office	
Fire Engine Tests and Fire Stream Tables (F)	Nat. Bd. Fire Underwriting	
Operation and Repair of Water Facilities in Civil Defense Emergencies ($0.25)	U.S. Govt. Printing Office	
Pamphlets on Story of Water ($0.05 to $0.10)	Am. Wat. Wks. Assn.	
Reprints of AWWA Committee Reports and Standards (order by number from list of AWWA publications)	Am. Wat. Wks. Assn.	
Silent Service Is Not Enough—Public Relations ($1.50)	Am. Wat. Wks. Assn.	
Water Rates Manual ($1.25)	Am. Wat. Wks. Assn.	
Water Rate Structures in America ($0.25)	Pub. Serv. Comm. of Wisc.	

C. Useful in Sewage Works

Copper Sulfate for Root and Fungus Control in Sanitary Sewers and Storm Drains, 1954 Ed. (F)	Phelps Dodge Refining Corp.	Phelps
Manuals of Practice Nos. 1,2,3,4,5,6 (various prices)	Fed. Sew. Ind. Was. Assn.	
Report of Committee of Great Lakes—Upper Mississippi River Board of State Sanitary Engineers—Bull. No. 42 ($1.00)	N. Y. State Health Dept.	

Addresses of Book Publishers

Publisher	*Address*
American Association for the Advancement of Science	1025 Connecticut Ave., N.W., Washington 6, D.C.
American Public Works Assn.	1313 East 60th St., Chicago 37, Ill.
American Society for Testing Materials	1916 Race St., Philadelphia 3, Pa.
American Society of Civil Engineers	33 West 39th St., New York, N.Y.
American Water Works Assn.	2 Park Ave., New York 16, N.Y.
Appleton-Century-Crofts, Inc.	35 West 32nd St., New York 1, N.Y.
B-I-F Industries, Inc.	345 Harris Ave., Providence, R.I.
Case-Shepperd-Mann Div., R. H. Donnelly Co.	305 E. 45th St., New York 17, N.Y.
Case Iron Pipe Research Assn.	122 So. Michigan Ave., Chicago 3, Ill.
Chemical Publishing Co., Inc.	212 Fifth Ave., New York 10, N.Y.
Crane Co.	836 So. Michigan Ave., Chicago 5, Ill.
Diesel Engine Manufacturers Assn.	1 No. La Salle St., Chicago 2, Ill.
Dorr-Oliver Co., Inc.	Barry Place, Stamford, Conn.
Federation of Sewage and Industrial Wastes Assns.	4435 Wisconsin Ave., N.W., Washington 16, D. C.
Hydraulic Institute	122 E. 42nd St., New York 17, N.Y.
Industrial Chemical Sales Div.	230 Park Ave., New York 17, N.Y.
International Text Book Co.	Scranton 9, Penna.
John Wiley & Sons, Inc.	440 Fourth Ave., New York 16, N.Y.
McGraw-Hill Book Co.	330 West 42nd St., New York 36, N.Y.
Missouri Water and Sewage Conference	State Office Bldg., Jefferson City, Mo.
National Board of Fire Underwriters	85 John St., New York 38, N.Y.
National Fire Protection Assn.	60 Batterymarch St., Boston 10, Mass.
National Lime Association	925 Fifteenth St., N.W., Washington 5, D.C.
North Carolina State Health Dept.	Raleigh, No. Carolina
N.Y. State Health Dept.	Albany 1, N.Y.
Phelps Dodge Refining Corp.	300 Park Ave., New York 22, New York
Public Service Commission of Wisconsin	State Office Building, Madison, Wis.
Reinhold Book Division	430 Park Ave., New York 22, N.Y.
Texas Water and Sewage Works Assn.	2202 Indian Trail, Austin, Tex.
The Chemical Rubber Co.	2310 Superior Ave., Cleveland 14, Ohio
The Chlorine Institute	50 East 41st St., New York 17, N.Y.
The Macmillan Co.	60 Fifth Ave., New York 11, N.Y.
The National Press	435 Alma St., Palo Alto, Calif.
The Permutit Co.	330 West 42nd St., New York 36, N.Y.
United States Government Printing Office	Washington 25, D. C.
W. A. Taylor & Co.	7300 York Road, Baltimore 4, Md.
Williams & Wilkins Co.	Mt. Royal & Guilford Aves., Baltimore 2, Md.

III. MANAGEMENT

The following section is devoted to the subject of management and the problems it entails. The brief outline below sets forth the several factors and phases that are important to the manager of either a water or sewage works, large or small.

Not every problem and phase of management is or can be presented in one issue but reference material not included in this issue will be found in other Reference and Data issues.

I. Financing
- A. Capital Expenditures
- B. Operation

II. Rate Schedules
- A. Funds Required
  - 1. Amortization
  - 2. Operation Costs
  - 3. Surplus and Contingency
- B. Type
  - 1. Flat
  - 2. Sliding Scale
  - 3. Volume
  - 4. Combined Water and Sewage

III. Office Operation
- A. Records
- B. Procedures
- C. Administration
- D. Personnel

IV. Public Relations and Policy
- A. Customer Relations
- B. Employee Relations

V. Lands and Laws
- A. Rights of Way
- B. Property
- C. Legal Restriction
- D. Commissions

VI. Safety
- A. Causes of Accidents
- B. Cost of Inquiry
- C. Program
- D. Practices

Management Problems Today

By LOUIS R. HOWSON
Partner, Alvord, Burdick, & Howson, Chicago, Ill.

MANAGEMENT in the abstract sense implies control or mastery. As applied to water works, good management is evidenced by the superiority of capacity over requirements, by revenues adequate to provide good service and finance expansion in advance of need, by the equitable apportioning of revenue requirements among those using the service, and by the general satisfaction of the users.

One of the prime attributes of management is timing. Good management anticipates rather than follows needs. Any water works that has not provided for future needs is habitually unable to meet the needs as they mature, whether they be physical or financial.

There are many types of management problems, including:

1. Being alert to the requirements for service, present and future.

2. Interpreting the service requirements in terms of facilities.

3. Assuring that the facilities are available when needed.

4. Carrying forward ordinary operations with economy and satisfaction to the consumers.

5. Anticipating the necessity for replacing property and making the financial arrangements that are required. (It is the author's belief that inasmuch as facilities furnish service, it is property rather than dollars that must be protected by the depreciation reserve.)

6. Raising the funds necessary to provide for the orderly expansion of the property to meet growing needs.

7. Providing revenues adequate to support the property and its services.

The author feels that the greatest single responsibility of management is to assure that its earnings are sufficient to enable it to supply the best service. As the cost of water service in the average American home is less than 1.5 cents a day per capita, the difference in cost between excellent and mediocre water service rarely exceeds a fraction of a cent per capita per day. This responsibility to assure the best service is shared by regulatory commissions.

Mr. Howson's article is reprinted from *J.A.W.W.A.*, Vol. 45, p. 1, by permission of the Association.

Coordination of Activities

Good management, therefore, forecasts its requirements for service, formulates a sound, well-distributed construction program, a sound financial policy, economical administration of operations, and the equitable allocation of revenue requirements through the medium of fair rates. All of these functions must be coordinated to effect a unified, interrelated procedure. Each function has its own problems.

Construction Program

The normal American water utility is a growing institution. The population which it serves rose approximately 35 per cent in the decade 1941-50. Water requirements (127 gpcd in 1945) are usually increasing at a rate of 1-2 gpcd per year.

The cost of supplying water works facilities over the past three decades has increased at least 2.5 times as fast as the population. In 1907 the U.S. census report showed the average book cost of water works to be approximately $30 per capita. Forty years later this figure was approximately $75 per capita. Recent cost-of-reproduction estimates of approximately twenty water plants show an average of 195 per cent of the original costs—that is, the cost of reproducing the average water works in 1952 would be approximately $150 per capita.

As all construction of new facilities must take place in the future, provision for financing must likewise be at future costs. The experience obtained from the Civil War, World War I, and World War II indicates that construction costs will never again be as much as 25 per cent below those of 1952. The Engineering News Record Construction Cost Index in October 1952 stood at 588.48 based on 1913=100. Cost-of-reproduction estimates indicate that water works construction reflects approximately 85 per cent of the increase in the general construction cost index.

It is part of good management for every water works, large or small, to have its future water requirements studied and its construction programmed and periodically reviewed for at least a decade in advance. If these precautions are taken, it will be practicable to coordinate construction and financing and thus make both much simpler and more economical. Only by advance study and planning can inadequacies and the accompanying consumer dissatisfaction be avoided.

The development of a well-considered construction program usually accomplishes the following:

1. It provides the funds required for construction when needed and not before. In this way it saves the fixed charges on expenditures which otherwise might be made before they are necessary, and eliminates the inadequacies in service resulting from delays in carrying out large expansion programs.

2. Construction and expenditures are made as uniform as practicable. A small expenditure for construction made each year is preferable to accumulated deficiencies corrected at infrequent intervals.

3. The development of such a program minimizes future obsolescence in that each year's construction, in addition to being designed to serve the immediate needs, is planned to fit in with ultimate requirements.

Financial Policies

Many of the problems of water works management are independent of ownership, whether public or private. Other problems, such as means of financing growth requirements and determining rates for service within and outside the city limits, differ appreciably in publicly and privately owned water plants.

Private water works are ordinarily financed approximately two-thirds by funded debt and one-third by equity money. The rates must be adequate to attract the necessary capital from both sources. Practically all private water companies are under the jurisdiction of public utility commissions that operate under statutes which, in general, prescribe that rates shall be sufficient to yield a fair return upon the fair value of the property. This general rule has in recent years been superseded in some states, including Illinois, by a "cost of money" basis. In applying this basis, the original cost of the property is reduced by the net credit balance in the depreciation reserve, the funded debt is deducted, and the balance is taken as representing the

equity interest in the property. Upon this equity interest, a rate of return of approximately 10 per cent is considered necessary to attract capital. On this basis, the equity owners get no compensation for the hazard in constructing and operating the two-thirds of the property represented by debt, and the rate base gives no consideration to inflation, the decreased purchasing power of the dollar, the reproduction cost, or the fair value of the property.

The continued application of this procedure, in the author's opinion, will seriously impair the financial credit of the water companies and their ability to provide the facilities which the consumers should have; consequently, the service will deteriorate. The author sees no justification for differentiating between the basis of valuing water works property and other properties with which the water works is competing for its financial requirements. "Fair value" fluctuates with the purchasing value of the dollar whether that dollar be expended in water works or in an office building. Inasmuch as it is a responsibility of management to provide capital for expansion, it follows that it is also its duty to see that earnings are adequate and properly determined in order that continuity of funds is assured.

Municipalities, on the other hand, operate under somewhat different conditions. Municipalities which have owned their water systems for long periods and have wisely managed them are either debt free or have small indebtedness. It is believed that the revenues of such municipal water works essentially consist of the sum of the requirements for operating and maintenance expenses, depreciation reserve, and the average annual needs for additions and betterments. This sum constitutes the amount to be collected from consumers within the city who are the stockholders in the municipal water plant.

The situation for service supplied by municipal plants to consumers located outside the city differs materially. Service to such outside consumers should be strictly on a utility basis. These consumers should pay rates adequate to yield a fair return on the fair value of the property. Under these assumptions, the inside-city consumers get their water substantially at cost, whereas the outside-city consumers pay higher rates in order to yield a fair return on the value of the facilities provided and paid for by others. Recently, in two cities in which inside and outside rates were figured on this basis, the outside rates were approximately 175 per cent of those inside the municipality.

Municipal plants should develop a sound financial policy designed eventually to retire indebtedness and get on a "pay as you go" basis. When this result is accomplished, the revenues collected through rates should be sufficient to pay operating and maintenance expenses; to provide an amount sufficient to cover ordinary additions to the water works such as distribution system extensions and meters; and to furnish an additional amount to cover the average annual requirement for major additions, this sum being apportioned and impounded during the period between such major additions.

Such a policy followed over a long period will result in the cost of water works expansion being approximately 40 per cent less than it would be under debt financing. Costs are amortized as incurred without interest charges.

Financing from revenues in municipal plants has the following advantages: 1. It provides new construction when needed without resorting to bond issues.

2. It avoids possible delays incurred by voting on bond issues.

3. It avoids the political exigencies which arise when bond issues are presented.

4. When such a financial program is properly developed in connection with a comprehensive construction program, the bulges in fixed charges due to bond issues are avoided.

5. The consumer's attention is focused upon service rather than cost, which is the main consideration when bond issues are presented.

6. Financing new construction from revenues reserves to the water department rather than the politician the control of its ability to finance, construct, and maintain high-quality service.

Conclusion

Good management does not just happen. It is created. Conferences in which mutual problems are discussed and experiences exchanged contribute to better management. The better the management, the fewer the problems that recur. Anticipation is superior to correction. The key to good management is planning, coordination, and timely execution of construction, financing, and operating procedures in a manner to meet the approval of the greatest proportion of the water users.

BLOTTING OUT WASTE

Safe Water
delivered night and day
Costs Less
than anything else you buy
•• but ••
Don't Ignore Leaks!

Satisfied customers are worth more to us than revenue secured from water uselessly passing through meters.

INDIANAPOLIS WATER CO.

What Leaks May Cost

Size of Leak		Gallons per 24 Hours	Gallons per Month	Cost per Month
½"	◯	47,600	1,451,800	$156.21
¼"	○	12,300	375,150	60.05
⅛"	o	3,200	97,600	19.65
1/16"	°	860	26,230	6.35
1/32"	˚	215	6,530	1.97

(Above estimates are based on Indianapolis pressure without allowance for friction loss)

The above is a reproduction of the top side of a little blotter sent out to customers, reminding them of the high cost of allowing fixture leaks to persist. If as good at blotting waste as ink, the scheme is praiseworthy.

Sewer Service Charges Based on Metered Water

by JOSEPH S. ROSAPEPE

Account Executive, Dudley, Anderson & Yutzy, New York, N. Y.

SEWER service charges based on metered water use are becoming more common as more communities seek to establish an equitable system of payment for sewage treament.

The trend toward setting sewer service charges on the basis of water consumption results from the recognition that most water distributed through a city's system eventually reaches the sewer system.

This practice is accepted as theoretically ideal because the sewer service charge is based on the volume of sewage contributed. In metered communities adoption of such charges is not difficult. Sewer charges based on metered water readings are simple enough to understand, easy to apply, and fair enough to be acceptable to the people in each community.

Charges can be expressed as a percentage of the water bill or as rates based on water consumption. Generally, the sewer rate is lower than the water rate. In some cases the water and sewer rates are combined into a single rate.

Setting of sewer rates based on metered water consumption "is coming to be the most popular and possibly the most equitable system of levying sewer charges," according to George H. Esser, Jr., Assistant Director of the Institute of Government of the University of North Carolina.

Advantages listed by Mr. Esser for sewer rates based on metered water consumption are as follows:

1. General practicality;
2. Smaller cost of billing and collecting sewer charges;
3. Greater convenience to the customer;
4. Closer relation of sewer use to water consumption;
5. Effective means of enforcing sewer charges by cutting off water for non-payment of the sewer service charge.

In his study of sewer charges, Mr. Esser was particularly concerned with the equitable level of rates adopted. He said:

"While sewer charges are a valid and lucrative source of revenue in financing the construction and operation of sanitary sewer systems and sewage treatment plants, rates should generally be readjusted somewhat in line with the principle recommended in the joint report issued by committees of the American Society of Civil Engineers and the American Bar Association."

This joint report stated:

"The needed total annual revenue of a water or sewage works shall be contributed by users and non-users (or by users and properties) for whose use, need and benefit the facilities of the works are provided approximately in proportion to the cost of providing the use and the benefits of the works."

This principle is reflected in the changing methods of setting sewer charges. Originally such charges came into being as a relief to the burden of the real estate tax, but in most cases were set on a flat-rate basis.

Puts Sewage Disposal on Self-Supporting Basis

Currently the trend toward charges based on metered water use is being speeded up by the goal of putting sewage disposal on a self-supporting basis. This, in effect, follows the pattern of what metered rates have done for water service.

A 1954 report by Floyd Browne and Associates, consulting engineers of Marion, Ohio, recommended a sewer service charge for construction of sewage disposal plant and a related network of interceptor sewers in Niles, Ohio, based on metered water use.

According to the report, such service charge to defray costs of revenue bonds is the preferred system used by municipalities today.

The report pointed out that a number of methods have been used to determine sewer charges — number of people in a household, sanitary fixtures per dwelling, number of factory employees, flat rates, or size of water meter or connection.

"All of the above methods are rapidly being superseded by the use of a rate based on water consumption," the consulting engineers' report said.

Among cities which use metered water rates for setting sewer charges are: Elkhart, Ind.; Bayonne, N. J.; Salem, Va.; South Bend, Ind., and others.

Typical Examples

Typical of the system used in some communities is the practice adopted in Waynesboro, Va., on the recommendation of the engineers for the sewage treatment plant. Users of the city's sewage works since July 1, 1954, are charged 60 per cent of their water bill to service the sewage bonds and maintain the treatment plant.

Users of the sewage works who live inside the corporate limits are charged a minimum of 90 cents. This is set on the basis of the first 1,500 gallons of water. Above that volume the charges are as follows: next 50,000 gallons, 24 cents per 1,000 gallons; next 150,000 gallons, 18 cents per 1,000 gallons; next 200,000 gallons, 12 cents per 1,000 gallons; and over 401,500 gallons, 9 cents per 1,000 gallons.

The rates for users outside the corporate limits are also 60 per cent, although the minimum is $1.80 and the rates per bracket for city users are doubled for each comparative division. This is due to the double rate for water users beyond the corporate limits of Waynesboro.

For private water suppliers, the city ordinance specifies that the amount discharged into the sewers shall be determined by meters provided by the consumer or at the consumer's expense with an applicable rate to be charged.

In Springfield, Ill., sewer charges based on metered water use went into effect in 1954 to pay for a long-range $9,000,000 sewer and sewage disposal improvement program.

The minimum service charges range from $1 per month upward. They are computed on a schedule of rates based on the monthly consumption of water per meter. The charges range from 20 cents per 100 cubic feet of water for the first 3,000 cubic feet to as low as 8 cents per 100 cubic feet for all water in excess of 30,000 cubic feet per month.

When the system was first introduced, the City Council issued a statement which said: "This is not to be interpreted as a raise in water rates. Rather, the system devised is a service charge against users of the sewer system, with billings to be made monthly through the City Water, Light, and Power Department."

At that time the Mayor of Springfield, in a formal statement, said:

"The rate ordinance establishes monthly service rates based on water consumption, computed on a graduated scale so that the heavier water consumers, who technically also are the heavier users of the sewer system, will pay the greater charges. On the average it is anticipated that approximately one-half of metered properties within the city of Springfield will pay only the monthly minimum of $1."

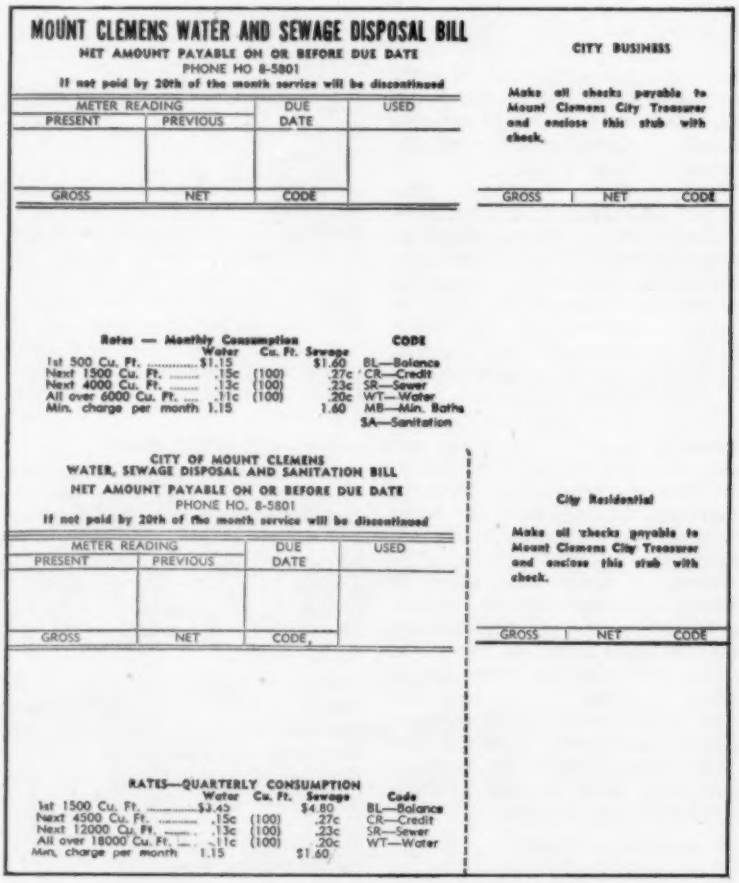
In Lawrence, Kan., a sewer rate was adopted in 1954 after a $3,000,000 water and sewer improvement bond issue was sold. The Lawrence schedule made outright provision also for disposal of "waste water from non-conserving air conditioning equipment," on the following basis:

For the first 10,000 gallons or less per month, $1.25 per month.
For the next 290,000 gallons per month, at the rate of $0.08 per 1,000 gallons.
Over 300,000 gallons per month, at the rate of $0.04 per 1,000 gallons.

In Fort Branch, Ind., the sewer charge starts with the minimum of $2.50 per quarter, to which is added 30 cents for every 1,000 gallons of water metered over 9,000 for the quarter. For example, a person who uses 12,000 gallons of water a quarter, for his sewage charge pays $2.50 for the first 9,000 gallons with the remaining 3,000 gallons being billed at 30 cents per 1,000 gallons, making a total bill of $3.40 for the quarter.

Galveston, Tex., in January, 1954, joined the cities using this advanced practice of levying sewer charges on the basis of water consumption after taxpayers authorized a $2,700,000 bond issue for the construction of a sewage treatment plant and interceptor line.

Sewer charges for industrial and commercial users, based on metered water bills are: First $5 of water bill, 40 per cent, $2 minimum charge; next $5 of water bill, 35 per cent; next $10 of water bill, 30 per cent; next $30 of water bill, 25 per cent; next $50 of water bill, 20 per cent; next $200 of water bill, 15 per cent;



MOUNT CLEMENS WATER AND SEWAGE DISPOSAL BILL
NET AMOUNT PAYABLE ON OR BEFORE DUE DATE
PHONE HO 8-5801
If not paid by 20th of the month service will be discontinued

METER READING PRESENT	METER READING PREVIOUS	DUE DATE	USED
GROSS	NET	CODE	

CITY BUSINESS

Make all checks payable to Mount Clemens City Treasurer and enclose this stub with check.

GROSS	NET	CODE

Rates — Monthly Consumption

	Water	Cu. Ft.	Sewage
1st 500 Cu. Ft.	$1.15		$1.60
Next 1500 Cu. Ft.	.15c	(100)	.27c
Next 4000 Cu. Ft.	.13c	(100)	.23c
All over 6000 Cu. Ft.	.11c	(100)	.20c
Min. charge per month	1.15		1.60

CODE
BL—Balance
CR—Credit
SR—Sewer
WT—Water
MB—Min. Baths
SA—Sanitation

CITY OF MOUNT CLEMENS
WATER, SEWAGE DISPOSAL AND SANITATION BILL
NET AMOUNT PAYABLE ON OR BEFORE DUE DATE
PHONE HO. 8-5801
If not paid by 20th of the month service will be discontinued

METER READING PRESENT	METER READING PREVIOUS	DUE DATE	USED
GROSS	NET	CODE	

City Residential

Make all checks payable to Mount Clemens City Treasurer and enclose this stub with check.

GROSS	NET	CODE

RATES—QUARTERLY CONSUMPTION

	Water	Cu. Ft.	Sewage
1st 1500 Cu. Ft.	$3.45		$4.80
Next 4500 Cu. Ft.	.15c	(100)	.27c
Next 12000 Cu. Ft.	.13c	(100)	.23c
All over 18000 Cu. Ft.	.11c	(100)	.20c
Min. charge per month	1.15		$1.60

Code
BL—Balance
CR—Credit
SR—Sewer
WT—Water

SEWAGE CHARGES based on metered water consumption in Mt. Clemens, Mich.
These bills for commercial (upper) and residential (lower) consumers carry the sewage rates and the water rate, expressed in cubic feet.

Niles, Ohio
Times 3/16/54

Plan to Use Meter System To Pay for Sewage Disposal

A ~~super~~service charge for construction of a Niles sewage disposal plant and related network of interceptor sewers, which it is estimated would cost the city $2,156,700, would probably be one based on metered water use.

According to a report released today to Mayor Edward P. Lenney and other city officials by Floyd G. Browne and Associates, consult-

Galveston, Texas
News 1/19/54

SEWER CHARGE PAYMENT BEGINS; ON WATER BILL

Water consumers are being billed their first time under the new sewer charge which became effective on Jan. 1, and there have ...aterworks Commissioner Marshall ...er, The News has received numer... mostly in the form of complaints. ...n. 6, and are continuing according ...ending out its notices.

...ized by taxpayers when the $2,700,... ...tion of a sewerage disposal plant ...d.

...l be paid off through the sewer ...ed for operation and maintenance ...its and replacements, McNeel said. ...roved by the citizens advisory com-

Roanoke, Va.
World-News 4/20/54

Separate Meter for Sprinkling Lawn Will Save Sewer Levy on That Water

Have you been irked over paying the city's 40 per cent sewage department debt assessment on water used for sprinkling lawns?

Then there is an answer.

Buy a second water meter and install it for lawn sprinkling only.

Then the water used for making the grass greener this summer will not be taxed as will be the water that goes down your sewer line.

But there is a catch.

Cost of the meter would be ... except that it is sprinkling ...

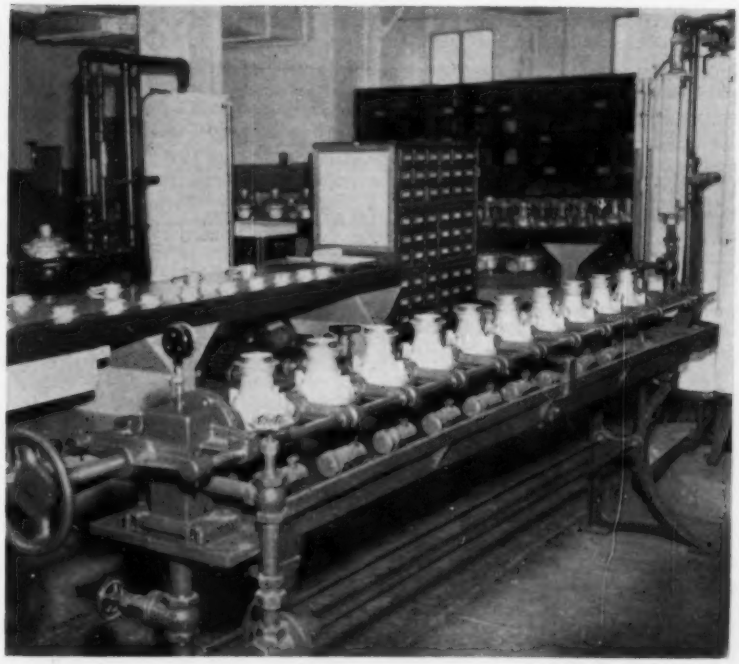
Wheeling, W. Va.
Register 3/3/54

Well-Water Users Pay Sewer Fees by Meter

By CHARLES GALLAWAY
News-Register Staff Writer

If you happen to know of a manufacturing plant that uses water from a well, don't think those plants which discharge clear water which is not contaminated as is the usual water going into the sewer system. Such non-polluted water can be diverted, even if it is purchased

TYPICAL of the trend toward sewage charges on the basis of metered water consumption are these newspaper headlines.



PROPER MAINTENANCE is the most important factor in assuring accuracy of meters. This test bench in the meter shop at Van Nuys, Calif., is typical of the testing facilities in some water systems.

next $300 of water bill, 10 per cent; and next $500 of water bill, 5 per cent.

More Examples

In January, 1954, Boulder, Col., increased its sewer rates and changed from a flat-rate charge to a proportional new sewer service charge system based on the amount of water used during the first quarter of each year.

It was estimated that the new schedule raised the average residential rate from the previous $2.14 a year to $5.47 a year. For all customers, including business places, the average cost went from $3.04 to $7.37, raising the city's revenue for the sewer maintenance fund from $16,300 in 1953 to an estimated $38,000 in 1954.

The annual sewer charge for customers with water meters is 3.5 cents per 1,000 gallons of water used, based on four times the metered water used during the first quarter of the year. Instead of figuring the sewer charge on the amount of water used in each quarter of the year, the charge for each of the four quarters is determined by the water consumption during the first quarter. The minimum sewer charge for metered water customers is $4 a year.

The new schedule provides no separate business rates because all business places have water meters, as do fraternity and sorority houses and the University of Colorado. Charges for customers outside the city limits are double those inside the city.

Perris, Calif., has a minimum charge of 50 cents per building, with a quanitty charge of $1 for each 4,000 cubic feet of sewage flow, which is assumed to be 90 per cent of the water usage unless the user submits evidence to the contrary.

A similar rate, based on consumption, is used in Redlands, Calif., where each business establishment, manufacturing plant and industrial building is charged for each sewer connection. The schedule provides for the following rates: 50 cents for the first 1,250 cubic feet of water used, 75 cents from 1,250 to 2,000 cubic feet, and for each additional 1,000 cubic feet an additional 40 cents.

In Troy, Pa., water and sewer rates were increased early in 1954 to put the city on a better financial basis. In 1953 the Borough water system received about $11,250 in revenue and spent about $14,750 for operation, maintenance and repair, representing a loss of $3,500.

The minimum water rate was raised from $2.50 to $3, affecting 90 per cent of the Borough's water users. When the sewer rates were raised, a large number of users were brought under the $2 minimum use charge. If a water user is charged for more than 6,000 gallons (the minimum), one-half of the water bill in excess lected by the sewer department in of th eminimum charge of $3 is coladdition to the $3 minimum charge for sewer service.

Some Disadvantages and Their Solutions

Despite the strong trend toward levying sewer charges on the basis of metered water consumption, some authorities have pointed to slight disadvantages in this method. These disadvantages are not serious enough, however, to lead to a reversion to flat-rate sewer charges.

Instances are noted where all the water consumed is not discharged into the sewer system, as in the case of lawn sprinkling and bottling of soft drinks. Another factor to be considered is that industrial sewage concentrations are not takeni nto consideration.

Some authorities say that generally it is best to make exceptions or special provisions for charging such industries as bottlers, ice companies, and those with air conditioning units.

The problem of water used for lawn sprinkling which did not go into the sewage disposal system brought on a unique development in Waverly, Iowa, in the summer of 1954. Utilities Superintendent Glen Yarger reported that he was getting requests for additional meters to be placed on faucets supplying water for gardens and lawns.

He said that the requests resulted from the much higher sewer rates now in effect in Waverly and that such requests came from people who did not want to pay sewer charges for water use don lawns and gardens.

In Marathon City, Wis., where the sewer charges are fixed at one-half the metered water bill ,consumers are credited for water used in lawn sprinkling which does not reach the sewer system. Bills for the period from July 1 to September 30 are based on water consumption for the preceding billing period.

The Marathon City ordinance also provides a credit for consumers where o portion of the water used is not discharged into the system. In this case the amount of water deducted in computing the sewer service charge is credited provided a separate meter is installed to record this portion of the water used.

In Wheeling, W. Va., the problem of levying a sewer charge against consumers having their own wells as a supply source was faced in the ordinance providing for the city's new $7,500,000 sewer system.

The oridnance setting up the sewer rates of one and one-half times the water bill did not overlook the customer who gets water from his own well or from any source other than the city water department.

If the water from such a source is not already measured by a meter, the law as proposed requires the owner to install, at hi sown expense, a meter which will satisfactorily measure the amount of water used so the sewer service charge can be established.

FLOW OF WATER IN HOUSE SERVICE PIPES

(To find the discharge in gallons, multiply by 7.48)

Condition of Discharge	Pressure in Main Pounds per Square Inch	Discharge in Cubic Feet per Minute from the Pipe								
		Nominal Diameters of Iron or Lead Service Pipe in Inches								
		½	⅝	¾	1	1½	2	3	4	6
Through 35 ft. of service pipe; no back-pressure.	30	1.10	1.92	3.01	6.13	16.58	33.34	88.16	173.85	444.63
	40	1.27	2.22	3.48	7.08	19.14	38.50	101.80	200.75	513.42
	50	1.42	2.48	3.89	7.92	21.40	43.04	113.82	224.44	574.02
	60	1.56	2.71	4.26	8.67	23.44	47.15	124.68	245.87	628.81
	75	1.74	3.03	4.77	9.70	26.21	52.71	139.39	274.89	702.03
	100	2.01	3.50	5.50	11.20	30.27	60.87	160.96	317.41	811.79
	130	2.29	3.99	6.28	12.77	34.51	69.40	183.52	361.91	925.58
Through 100 ft. of service pipe; no back-pressure.	30	0.66	1.16	1.84	3.78	10.40	21.30	58.19	118.13	317.23
	40	0.77	1.34	2.12	4.36	12.01	24.59	67.19	136.41	366.30
	50	0.86	1.50	2.37	4.88	13.43	27.50	75.13	152.51	409.54
	60	0.94	1.65	2.60	5.34	14.71	30.12	82.30	167.06	448.63
	75	1.05	1.84	2.91	5.97	16.45	33.68	92.01	186.78	501.58
	100	1.22	2.13	3.36	6.90	18.99	38.89	106.24	215 68	579.18
	130	1.39	2.42	3.83	7.86	21.66	44.34	121.14	245.91	660.36
Through 100 ft. of service pipe and 15-ft. vertical rise.	30	0.55	0.96	1.52	3.11	8.57	17.55	47.90	97.17	260.56
	40	0.66	1.15	1.81	3.72	10.24	20.95	57.20	116.01	311.09
	50	0.75	1.31	2.06	4.24	11.67	23.87	65.18	132.20	354.49
	60	0.83	1.45	2.29	4.70	12.94	26.48	72.28	146.61	393.13
	75	0.94	1.64	2.59	5.32	14.64	29.96	81.79	165.90	444.85
	100	1.10	1.92	3.02	6.21	17.10	35.00	95.55	193.82	519.72
	130	1.26	2.20	3.48	7.14	19.66	40.23	109.82	222.75	597.31
Through 100 ft. of service pipe and 30-ft. vertical rise.	30	0.44	0.77	1.22	2.50	6.80	14.11	38.63	78.54	211.54
	40	0.55	0.97	1.53	3.15	8.68	17.79	48.68	98.98	266.59
	50	0.65	1.14	1.79	3.69	10.16	20.82	56.98	115.87	312.08
	60	0.73	1.28	2.02	4.15	11.45	23.47	64.22	130.59	351.73
	75	0.84	1.47	2.32	4.77	13.15	26.95	73.76	149.99	403.98
	100	1.00	1.74	2.75	5.65	15.58	31.93	87.38	177.67	478.55
	130	1.15	2.02	3.19	6.55	18.07	37.02	101.33	206.04	554.96

Administration of Small Water Plants

By WENDELL R. LA DUE
Chief Engr. and Supt., Bur. of Water and Sewerage, Akron, Ohio

WHAT is administration? The words management and administration are synonymous and mean the conducting or carrying on of affairs—of a business, for example. That business can be a water works. An error is frequently made in thinking of the large-plant man and the small-plant man as two different kinds of men. In fact they are not, for they are the same kind of man in constant and daily need of different approaches to the same kinds of problems. Progress in solving the management problems of the small plant cannot be made by driving imaginary wedges between large water utilities and small ones, or by assuming that one is enlightened, well meaning, and knows all the answers, and the other is not and, therefore, must be "managed."

When does a plant cease to be "small" and become "large"? There are now more than 100,000,000 people in organized communities in this country who receive safe and dependable water supplies from publicly and privately owned water utilities. On the average, this service is supplied by one employee for each 1,250 people served. In other words, 80,000 people serve 100,000,000. This is big business ,whether a community is served by 5 or 5,000 employees. These 80,000 persons, each possessing an almost infinite variety of skills, training, and talents, every day of the year without ceasing, are contributing unselfishly and selflessly of their energy, ability, and ingenuity to the biggest business, in tonnage, in the United States. There is no precise or scientific way by which the achievement or contribution of each can be measured. But this is not important. It is necessary, though, that the water works profession foster among its members a broad and sympathetic understanding of the mutual responsibilities and problems of small and large plants. Such an understanding among water works men will result in greater encouragement from the public.

Why should the water works industry improve its administration? Good management is the result of a combination of continuing policies, including expansion of both facilites and operations, sound financing, efficient conduct of business, and satisfying services. Good management is as essential for small plants as it is for large water works systems. All too often management is considered to be confined to the direction of more or less routine operating functions. In a practical sense, it must include sound planning for the future and the coordination of needs, plans, and accomplishments with the financial obligation and ability of the community to support them.

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Water Works Administration Committee

The water works profession will accomplish much to improve its own status if it can produce an enlightened and progressive top management. The purpose of the American Water Works Association's Committee on Water Works Administration is to do just that, as illustrated by the purposes of its various subcommittees:

Constitutional and Statutory Aspects of Municipal Water Works Organization—charged with the duty of studying existing state and province laws and municipal ordinances, and formulating principles relating to types of municipal water works organizations.

Radio and Mobile Communication Facilities for Water Works—charged with the study of the use of radio and mobile communication facilities available for water works, together with the collection of data on the use of radio in the water works field. The committee has a continuing interest in federal activities affecting wave allocation to utilities.

Water Used in Air Conditioning and Other Refrigeration — charged with the study of the problems arising from the use of water in air conditioning and other refrigeration and to recommend policies as they affect water works (and sewage) facilities.

Water Use in Fire Prevention and Protection—charged with the study and evaluation of methods of fire prevention and protection and of protecting sprinkler systems from freezing. This committee may be expanded to meet the pressing problem of renegotiation of insurance contracts to meet the demand sensed in increased costs of replacement.

Public and Worker Relationships—charged with: [1] considering and proposing to the Board of Directors activities on behalf of the Association in the field of public relations; [2] the production of guidance material in the field of public relations; and [3] the review of material which is in process of production by the Association.

Compensation of Water Works Personnel—charged with the gathering of comparative material and data and the formulating of a general schedule of compensation for water works personnel and management.

Pension and Retirement Plans—charged with the duty of collecting information upon, and promoting the adoption of, pension and retirement plans in the public water works industry, as well as the study of developments in the industrial field and their effects upon public employees.

Safety Practices—charged with the preliminary study of personnel safety and working conditions in plant facilities and physical structures. This study may be extended later to the border field of public safety in water utility construction work. This particular field of management is attracting nation-wide attention.

Taxation and Revenue Allocation—charged with the assembly and study of data on the taxation of water works systems and the diversion of funds from the water works utility to other activities, and the formulation and distribution of basic principles of good management of taxation and revenue allocation.

Water Main Extension Policy—charged with the study of the problems involved in the extension of water mains, both within and without the corporation limits, including a digest of enabling legislation.

Water Department Reports—charged with the review of existing annual reports of water works organizations and the preparation of recommendations on content and style of annual reports.

Water Rate Schedules — charged with the consideration of the fundamentals of water rate structures and the outlining of the policies upon which rate schedules may be developed in order to distribute equitably the funding, operating, and maintaining of water works utilities.

Water Use—charged with the collection and evaluation of data on:

1. Industrial water use, encompassing the water requirements of specific industrial operations and involving the collection of information from units in the same industry over a wide geographic area, in order that water requirements per unit of product may be tabulated.

2. Domestic water use, encompassing the collection of data from a number of water utilities from which a breakdown is available to show per capita water use in different types and sizes of residences and various classes of commercial establishments.

Forms of Management

Is it not possible that these problems of administration result from the inadequate attention that is given to management spend its time discussing the results of inadequate management, whereas it ought to be doing something about analyzing the causes, diagnosing the resulting weaknesses, and then taking the steps necessary to correct them? Realizing the impractical multiplicity of state laws, local ordinances and charters, is this truly not a challenging problem? At the very outset, water works men themselves become quite philosophical and altruistic in realizing and appreciating the the fundamental reasons for their occurrence? Does not water works other fellow's position. The ramifications are many but the generalities few.

There are many cities in which the water works management is directly under the city council, the personnel of which, by nature, is continually shifting. In such a setup, centralized top responsibility is generally slight, as there is no real concern about long-range planning for the work of later administrations. There are very often too many potential "bosses," and the superintendent, no matter how efficient, may be subject to change with the city administration.

Water works management under the city manager form of government is only as good as the city manager, who, in turn, is subject to the changes and whims of a council or other elected board of similar nature. When a city manager is changed, his appointees usually go with him.

A third general form of top management is that of the special water works commission, usually consisting of three to five men with overlapping terms of such lengths that, in general, no one political administration can upset the board by a majority of new appointments. Such a board is responsible to no one but the public which it serves. It is nonpolitical; its continuity is assured and it attracts to its membership the best qualified men of the community. This form of management lends itself to a continuity of employment of water works personnel; the maintenance of high efficiency; the establishment of constructive, continuing policies on construction, operation, and rate stability; and the furnishing to the consumer of a maximum of satisfying service at a minimum of justifiable expense and cost.

In all local organizations, management is brought face to face with one of the most baffling challenges of human nature and behavior: "People get and do what they want, good or bad." When a superintendent in the near-perfect protection of an ideal, commission-operated water works asks why a certain city countenances the shortcomings of some council-controlled operation, the only answer forthcoming may be "Because they (the people) want it and like it that way." For this reason, regardless of its logic, a uniform type of top management is not always potentially possible or perhaps even actually desirable. Past history and local conditions will weigh heavily and must be considered.

Legislation

It appears quite evident that practically every undertaking of a water department is connected in some way with the basic and enabling legislation applicable to the actual organization of any department in any particular state. Water works management must be continually aware of this constantly changing legislation. Pennsylvania affords an outstanding example of this observation. Under the "Authorities Act" of 1935, 71 water works management and ownership groups were functioning in 1950.

The series of legislative enactments known as the "authority acts" permits the citizens of a single city or town or of groups of incorporated and unincorporated places to establish an agency through which governmental units may provide needed facilities and services for themselves, upon a self-liquidating basis, in the manner of private industry and without obligating the pre-existing units of government. Such an authority is authorized to file liens for debts owed, is given the power of eminent domain (but not the power to acquire a water works or other system by condemnation), can sue and be sued, and can issue revenue bonds, but may not obligate the municipality. The life of an authority under the Pennsylvania acts is limited to 50 years, whereas bond issues are limited to 40 years and the maturity of refunding bonds is restricted to the life of the authority. At the termination of the life of an authority, its property may revert to the municipality of municipalities which incorporated it. One further stipulation, which is of great value, requires that for the period during which authority revenue bonds are outstanding, an engineer must be retained by the authority to advise it on matters of planning and management.

Authorities have been given the power to assess benefited properties for the cost of improvements in proportion to the benefits received, giving them, in this respect, an advantage over private companies which must establish a rate structure that will make them entirely self-supporting from revenues or rentals. Private companies are permitted no other sources of income and may not be parasites on any municipal funds, except, possibly, when a system is leased to the municipality for operation. On the other hand, authorities cannot be deprived of their revenues to carry out other municipal functions.

The populations served by various Pennsylvania water authorities in 1950 varied from 700 to more than 100,000. By the end of 1947, 65 water authorities served more than 1,300,000 consumers and the total assets of the group were in excess of $101,250,000.

Conclusion

The procedures discussed support the idea that there is no real difference in the objectives of the "large" and the "small" plant. The author gives well-deserved praise to the small operator. He has sometimes been compared to a one-man ball team. Just as busy, he pitches the ball, runs behind the plate to catch it, and, if it is hit, he runs to the outfield to catch it, or attempts to put out the runner, all by himself. In other words, he treats the water, operates the plant, distributes the water, reads the meters, bills the customers, and collects the money, all with the utmost confidence that things will "come out all right in the end." The large-plant operator may be compared to the president of the league, but he has no more fun, nor do his customers have more confidence in him than in the small operator. The author knows no other career that affords a greater sense of inner satisfaction to those who embrace it successfully nor another business in which there is greater determination to do a better job.

Commercial Records*

Four simple and basic forms for Small Water Works

by W. F. GORDON
Division Comptroller, American Water Works Service Co., Palmyra, N. J.

ANY DISCUSSION on the subject of commercial records for small water systems immediately raises two questions, the first being how to define a "small" water system and the second relating to the importance that should be placed on commercial records or customer accounting.

A small water system could be defined as one serving any of the small towns or villages having a population of up to possibly 10,000 persons. Using the national average of about 4 persons per family, this would mean a system serving up to 2,500 customers.

Customer accounting could probably be defined, from an accountant's standpoint, as the heart of any water system. Through its efficient operation "flows" that life giving substance, more commonly called "cash," that is so essential to any successfully operated business. This is particularly important for the small water system where the gross revenue received in a year's time is probably less than that of the corner grocery store.

*Reprinted from JAWWA 47,259 (1955) by permission.

COMPANY — WORK ORDER NO.

ACCOUNT NAME — ACCOUNT NO. — Deed

Location — Town

WORK TO BE DONE:

- ☐ Turn on—Install Meter
- ☐ Turn off—Remove Meter
- ☐ Change Meter
- ☐ Investigate High Consumption
- ☐ Investigate Slack Pressure
- ☐ Investigate Leak at Curb—In Street
- ☐ Investigate Leak at Meter
- ☐ Install—Renew—Service

WORK DONE AND INFORMATION:

Account Name Changed to:
Mail Bill to:
New Owner—Tenant:
Work Requested by:
Key From
Street Permit No. — Date — Cost
Type Paving — Size Opening
Turned on at Curb — At Meter
Turned off at Curb — At Meter
Meter No. — Installed Reading — Gal.
Meter No. — Removed Reading — Gal.
Work Started — A.M.—P.M.
Work Completed — A.M.—P.M.
New Work — Renewal — Repairs — Changes
Meter Reading:

Units	Size	MATERIAL USED	Unit Cost	Total Cost
		Copperhorn		
		Coppersetter		
		Barrel and Top		
		Copper Service Pipe		
		Galv. W. I. Pipe		
		Cast Iron Pipe		
		Galv. W. I. Nipple		
		Stop and Waste		
		Ell		
		Service Ell		
		Union		
		Tee		
		Extension Piece		
		Socket		
		Service Clamp		
		Corporation		
		Eighth Bend Connection		
		Curb Cock		
		Coupling—Copper to Copper		
		Coupling—Copper to Iron		
Charge Acct. No.		Total		

Signed

TIME — NAME	Hours	Rate	Total

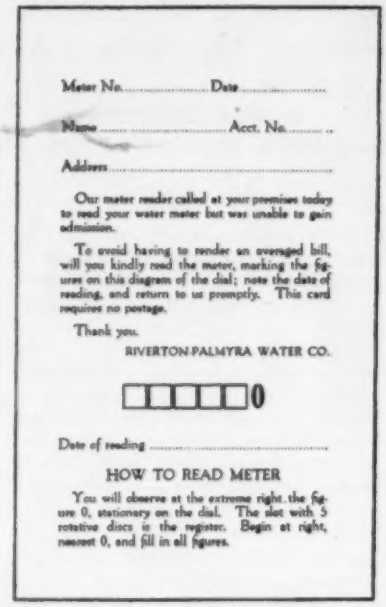
and the monthly report of materials issued from stock.

Meter Book

The meter book is the biography of the customer's account. For this reason the meter reading sheets should be of sufficient size to accommodate meter readings for approximately a six-year period, assuming meters are read quarterly. Columns should be provided not only to include date of reading, meter registration, and consumption, but also for remarks and the amount of billing. (Fig. 2).

It may appear that the listing of the amount of billing on the meter sheets is a duplication of work. However, the advantages in the investigation of customer complaints, in preparing average bills where meter readings could not be obtained, and in other analysis work that may from time to time become necessary, more than compensate for the additional work of adding this information to the meter sheets.

The space for "remarks" also can be used to advantage. When the meter reader cannot obtain a reading it is sometimes advisable to leave a self-addressed, stamped postage card on which the customer may list the reading. When such a card is left with the customer, a notation to that effect may be made in the meter reading book. This space is also beneficial in noting any unusual usage or leakage that may result in high consumption and the resultant high water bill. This type of information is most helpful to the office clerk in the preparation of the water bills.



Meter No. ..... Date .....

Name ..... Acct. No. .....

Address .....

Our meter reader called at your premises today to read your water meter but was unable to gain admission.

To avoid having to render an averaged bill, will you kindly read the meter, marking the figures on this diagram of the dial; note the date of reading, and return to us promptly. This card requires no postage.

Thank you.

RIVERTON-PALMYRA WATER CO.

□□□□□0

Date of reading .....

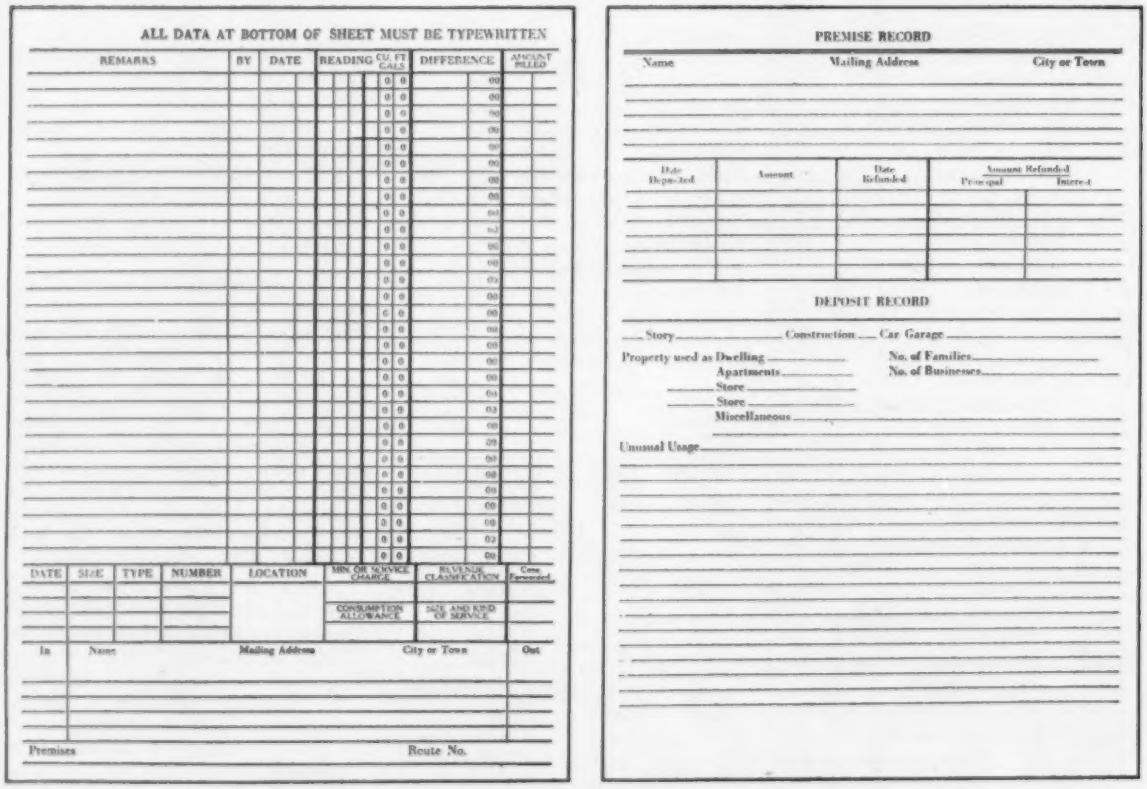
HOW TO READ METER

You will observe at the extreme right the figure 0, stationary on the dial. The dial with 5 rotative discs is the register. Begin at right, nearest 0, and fill in all figures.

Fig. 3. Customer Meter-reading Card
The card can be adapted for use with dial meters.

The postage card that may be left at the home where readings cannot be obtained is pre-printed with the dial face of a meter, where round reading meters are used. The customer indicates the position of the dial hands on the card. Companies using straight reading meters may use cards with blank blocks where the customer may insert in the appropriate blocks the numerals appearing on the meter. (Fig. 3.) Generally a time limit of three days is allowed for the customer to return the card to facilitate billing.

In systems where there are no meters, billing is usually based on the number of fixtures found in the home. For this type of billing it is necessary to use a flat rate fixture survey ledger in lieu of a meter book. This form (Fig. 4) provides for a listing of the different types of fixtures, and the



ALL DATA AT BOTTOM OF SHEET MUST BE TYPEWRITTEN

REMARKS | BY | DATE | READING CU. FT CALS | DIFFERENCE | AMOUNT BILLED

DATE | SIZE | TYPE | NUMBER | LOCATION | MIN. OR SERVICE CHARGE | REVENUE CLASSIFICATION | Cons. Forwarded

CONSUMPTION ALLOWANCE | SIZE AND KIND OF SERVICE

In | Name | Mailing Address | City or Town | Out

Premises | Route No.

PREMISE RECORD

Name | Mailing Address | City or Town

Date Deposited | Amount | Date Refunded | Amount Refunded: Principal | Interest

DEPOSIT RECORD

Story ____ Construction ____ Car Garage ____

Property used as Dwelling ____ No. of Families ____
Apartments ____ No. of Businesses ____
Store ____
Store ____
Miscellaneous ____

Unusual Usage ____

Fig. 2. Meter Book Sheet
Left—front; right—back. The actual page size is 6 x 9½ in., including margin for holes punched at top of front side.

rate applicable to each type. The form usually includes space for the listing of additional fixtures that may be found in future surveys. Provision of space for future surveys eliminates the necessity of preparing a new ledger sheet each time a fixture survey is made. Hereagain it is essential to provide space to record the amount billed during each billing period.

Customer's Bill and Ledger Form

The customer's bill and ledger form considered here is often termed a three-part bill or post card billing. The trend over the past two decades or so toward this type of billing has been brought about primarily by the ease of handling and the savings in postage costs. This type of bill consists of three parts; namely, the customer's bill, the cashier's stub, and the ledger card. (Fig. 5).

Assuming that the system is metered, and that the billing will be prepared by hand, the customer's bill should be designed to show the date the bill is rendered, the present and previous meter readings, the dates on which the readings were obtained, the volume of water consumed, and the amount of the billing. Provision also should be made for showing any arrearages that may be due. In order to conform to postal regulations, arrearages should be designated as "other charges." If there is sufficient space available, it also may be desirable that the customer's bill show the schedule of rates. However, many companies eliminate this from the bill, simply making reference that a schedule of rates may be obtained at the company's office.

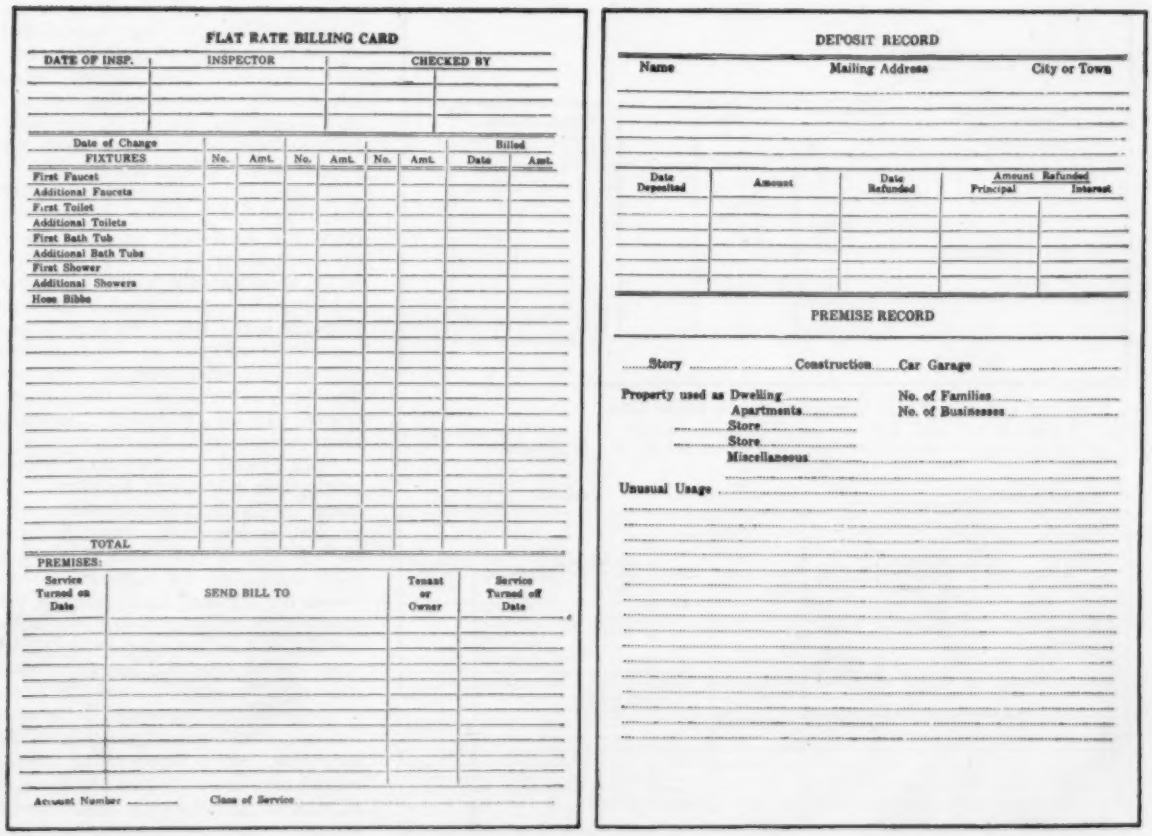
The cashier's stub should show the date of the bill and the total amount due.

The ledger card should show the date of the billing and the total amount due. There also may be provision for showing the meter readings and consumption. This information is of secondary importance, however, as it is readily available from the meter book. In addition, provision should be made for the listing or recording of partial payments. It also may be desirable to provide a space for the determination of the age of delinquent accounts. This can be accomplished by listing the dates of previous unpaid bills and the amounts applicable to each period.

Route Control Ledger

A system of control is necessary for the activity of the customers accounts. This is accomplished by the use of a route control ledger. For all general purposes, there should be a route control ledger sheet for each meter book. In other words, if a meter book contains 100 accounts, there should be a route control ledger sheet for those accounts. The route control ledger sheet should be designed to record, by days, the activities within the accounts for a period of one month.

The simplest type of form should provide columns for listing the balances of unpaid accounts at the beginning of the month, the billings made during the month, the cash collected during the month, allowances and discounts given during the month, and the balances of unpaid accounts at the end of the month. (Fig. 6). A more elaborate form would provide columns for listing such items as checks that may be returned, applying customer guarantee deposits towards



FLAT RATE BILLING CARD

DATE OF INSP. | INSPECTOR | CHECKED BY

Date of Change | Billed

FIXTURES | No. | Amt. | No. | Amt. | No. | Amt. | Date | Amt.

First Faucet
Additional Faucets
First Toilet
Additional Toilets
First Bath Tub
Additional Bath Tubs
First Shower
Additional Showers
Hose Bibbs

TOTAL

PREMISES:

Service Turned on Date | SEND BILL TO | Tenant or Owner | Service Turned off Date

Account Number ..... Class of Service .....

DEPOSIT RECORD

Name | Mailing Address | City or Town

Date Deposited | Amount | Date Refunded | Amount Refunded: Principal | Interest

PREMISE RECORD

Story ..... Construction ..... Car Garage .....

Property used as Dwelling ..... No. of Families .....
Apartments ..... No. of Businesses .....
Store .....
Store .....
Miscellaneous .....

Unusual Usage .....

Fig. 4. Flat-Rate Ledger Sheet
Left—front; right—back. The actual page is 6 x 9½ in.

the payment of bills, and various other transactions that may arise.

How the Forms Are Used

The mechanics of maintaining a system of customer accounting with these four basic records is quite simple.

The use of the service record form, as the name implies, is self-explanatory. One thing, however, should be borne in mind — an addressograph plate and meter reading sheet should be prepared as soon as possible after an application has been received for water service.

The first step in the billing procedure is to address the customer's bill, cashier's stub and ledger cards. The addressograph plates should be in the same chronological order as the meter reading sheets, thereby eliminating the sorting of bills during the billing period.

After the meters have been read, the water consumption is computed and the amount of each bill is determined from a billing chart. All of this information is entered in the meter book. It then is only necessary to copy the information from the meter book to the customer's bill and ledger card. Immediately preceding the mailing of the bills, any unpaid amounts from the previous billing period should be transferred to the current bills and ledger cards.

Upon completion of the billing, three adding machine tapes should be run. The first is run on the amounts billed to determine the total billing; the second is run on the amounts due, which will include unpaid amounts from the previous billing period; and the third is run on the consumption to determine the amount of water sold.

The total amount of billing as determined by the first tape is recorded on the route control ledger in the column provided. This amount, when added to the previous balance of unpaid accounts as shown on the route control sheets, should agree with the total obtained on the second tape.

At this point in the billing procedure the ledger card section is detached from the customer's bill and these cards are placed in a security file. One of the most common methods of filing is to separate the file drawer into two sections, using the front section for the unpaid accounts and the back section for the paid accounts. The one drawback to this type of filing is the trouble that can be caused if one card becomes lost or misplaced.

Each group of ledger cards representing the number of accounts in a meter book should be fastened together. This can be accomplished by having the printer pre-punch the ledger card section of the bill midway between the top and the bottom of the card on the extreme left. The cards are then joined together with a common metal paper fastener, purchasable at any stationery store.

In the posting operation for the payment of customer accounts, it is necessary that every payment be represented by a cashier's stub. At the end of each day's activity the cash drawer should be balanced against the stubs, so that in the event of error the chances of finding the mistake are

The Riverton and Palmyra Water Company
Office: Morgan and Bank Aves., Palmyra, N. J.

Bill for Water Service

METER READING IN GALLONS		Consumption in Gallons	AMOUNT DUE
Present	Previous		
00	00	00	$

If receipt is required, present entire bill, or mail with stamped, addressed return envelope.

Arrears

CONSUMER'S RECORD

Paid by Check No. ____ Date ____ Total $

Schedule of Rates

Fixed Service charge per Quarter For: ⅝ in. Meter $1.50; ¾ in. Meter 2.70; 1 in. Meter 5.40; 1½ in. Meter 13.50; 2 in. Meter 18.00

Plus Water Consumed: First 30,000 gals. 40c per M; Next 30,000 gals. 35c per M; Next 30,000 gals. 30c per M; Next 50,000 gals. 25c per M; All over 120,000 gals. 15c per M

Minimum Bill, $4.00 per Quarter. Fixed Service Charge payable in advance. Bills are due within fifteen days of date; prompt payment is requested.

Detach this Stub and mail with Check

$ ____

Total

Riverton and Palmyra Ledger

Meter Reading Dates		Consumption in Gallons	Amount Due
Present	Previous		
00	00	00	$

Arrears

Payments Total

Analysis of Arrears		
Date	Amount	
Total		

Fig. 5. Customer's Bill and Ledger Card

Top—bill and cashier's stub; bottom—ledger card. The ledger card, originally attached at the right of the cashier's stub, is removed before the bill is mailed.

For Month Ending _____ Route No. _____

	Explanations	Balance Beginning of Month	Billing	Penalties	Credits			Balance End of Month
					Cash	Allowances and Other Credits	Discounts	
1								
2								
3								
4								
5								
6								
7								
8								
27								
28								
29								
30								
31								
	Total Month							

Fig. 6. Route Control Ledger

A sheet of this type is kept for every route number, and entries are made daily.

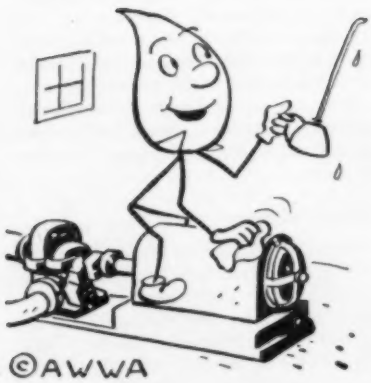
greater than if the cash drawer is balanced only once or twice a week.

Each day's collection of cashier's stubs is sorted and placed in numerical sequence, and route order. An adding machine tape on the amount of these stubs should be run by account and route order. The total of the tape represents the collections for the day, and this amount should be deposited in the bank. The total amount collected in each route is posted to the route control ledger sheet. The individual payments are posted to the ledger card by stamping the card with the date of payment.

Those ledger cards that are paid in full are then turned to a position directly opposite the accounts that remain unpaid. By placing the paid cards in this position, one has a visual knowledge, at any time, of the number of accounts with outstanding balances.

At least once a year there is generally a requirement to furnish a count of customers. This can be accomplished by placing in the back of each meter book a fly sheet on which is noted the number of accounts contained in the book, classified as to the type of service (such as residential, industrial, etc.) This count can be kept up to date by adding each new account and deducting each account that has been turned off.

It is obvious that these are only a very few of the many and varied types of forms that can be and are being used in commercial accounting in water utilities. However, the four basic forms described herein are believed to be completely adequate for the requirements of most small water systems.



Storage for Large Maps and Plans

by DORA H. PARKER
Draftsman, Alabama Dept. of Public Health, Montgomery, Ala.

ALTHOUGH the matter of storing the accumulating volume of records of smaller dimensions has been eased somewhat by microfilming, storage of larger records, such as maps and plans, presents a problem in proportion to their size.

A particular problem of storage for water and sewer plans for the various Alabama cities and towns arose recently when the Bureau of Sanitation of the State Health Department moved into quarters in the New State Office Building in Montgomery, Ala.

The plans, representing the accumulation over the years for each city and town of Alabama, must be kept intact from the first record of installation to the latest proposed addition, because approval of proposed additions and extensions to any plant requires that the total picture of each system must be available for review at all times.

The plans are approximately 30 inches by 42 inches and consist of from 1 to 25 or 30 sheets per plan. The total space required for storing the current file of some 7,000 sheets of permanent records, plus the normal yearly increase of plans approved by the State Health Department, was the first consideration in approaching the problem. The second consideration was to design storage that would provide adequate space and be easily accessible for filing and reference. There also was the more practical aspect of keeping the cost down by not using special fittings.

Considerable thought and discussion on the matter resulted in the design described herein. The result has been eminently satisfactory and this facility is suggested to those who might have a similar problem of storage for large permanent maps and records. The device is particularly adaptable due to its construction from readily available stock supplies.

Construction of Rack

The entire wall of a storage room was used to build the two-deck rack (Fig. 1) from which the plans were hung. The rack was built in place with 2x4's, the three lengthwise pieces forming the top framework of each deck being placed on edge for strength. The wall being approximately 18 feet long, three supports with diagonal braces were placed at approximately 4-foot 2-inch intervals for added strength. A base built to conform to the rack dimensions was laid flat and bolted to support the structure.

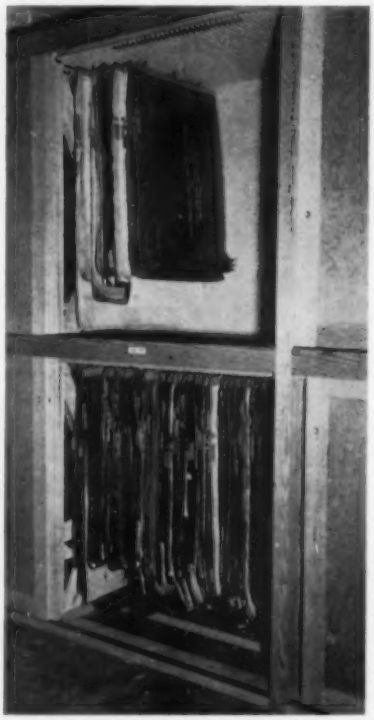


FIG. 1—CURTAIN RODS provide space-saving storage for large plans

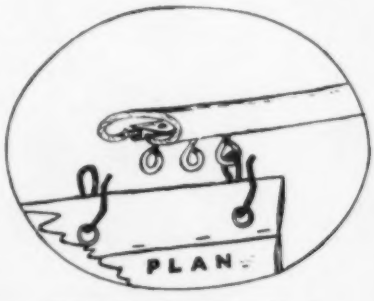


FIG. 2—DETAIL of track and hooks

The back and top are covered with ⅛-inch masonite. Four sets of sliding doors complete the compartments.

For hanging the plans, 30-inch lengths of Kirsch overhead tracks (heavy-duty drapery rods) with three slides for attaching the plans by means of drapery hooks were set on 1-inch centers and fastened to the three overhead 2 x 4's by means of screws. The ends of the tracks were crimped to retain the slides.

This arrangement provides 50 tracks in each of the four upper and lower compartments, or a total of 400 tracks.

The plans are indexed numerically and alphabetically, then grouped as nearly as possible according to city and plant identification. The thickness of each group of plans is kept to a maximum of approximately ¾ inch.

They are then bound with 3-inch heavy manila gummed tape. Three brass eyelets through the bound edge 2 inches from each end and at the center permit drapery hooks to be inserted in each eyelet.

The plans are then ready to file. This is done by simply inserting the hooks into the projecting swivel loops of the slides, beginning with the back hook into the back loop (see Fig. 2).

Plans can thus be filed or withdrawn easily by either inserting the hooks or disconnecting the hooks from the slide loops one at a time and inserting or withdrawing the plans, as the case may be. The crimped ends of the track retains the slides and the hooks remain attached to the plans.

Its economy of construction and its ease of operation commend this storage scheme to those who need this type of storage.

Acknowledgments

Acknowledgment is made to the following who contributed largely in the design of the plans through suggestions, questions and encouragement: C. W. White, Assistant Sanitary Engineer; R. V. Barnes, Assistant Sanitary Engineer; W. H. Gilmore, Assistant Sanitary Engineer; Joe L. Crockett, Jr., Assistant Sanitary Engineer; and Arthur N. Beck, Chief Engineer and Director, who approved the plans and directed the installation.

Equitable Charges for Fire Protection

Public fire protection costs computed by the "Incremental Cost Method" are substantially lower than costs determined by other methods

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THE PRIMARY requirement of a waterworks system is that it have the capacity to perform its two principal functions; the supply of water for general consumption and the supply of water for fire protection. From the performance of these two functions a water works usually secures its revenue, in the form of charges for the water consumed and charges for the fire protection service afforded. It is obvious that the most equitable method of distributing charges is for the *consumer* to pay for the actual water used for general consumption, and for the *property protected* to pay in addition for fire protection. There is a difficulty, however, in determining what constitutes equitable distribution of charges.

Allocation of Service Costs

For many years there has been general agreement on the principle that each function of the water works system should pay for the cost of providing that function. With this in mind, the various items of expense in the water works budget, such as hydrants, meters, services, etc., can be assigned to the function for which the item is used. For example, hydrants, including their connections and gates, should be assigned to fire-protection charges; services, meters, small distribution mains, and purification works should be assigned to the functions of general consumption. Any other special service, such as private fire protection, should be charged to that service.

The allocation of the cost of remaining parts of the assets of the water works, which are used jointly by fire protection and general consumption, can be made by the following general methods: (1) public fire protection as an incremental cost, (2) general service as an incremental cost, and (3) the capacity-ratio method.

The "capacity-ratio method" assumes that fire protection is of no less importance than general service; it provides for the allocation of costs of a joint nature on the basis of some relation between the capacity required for public fire protection and the capacity required for general service. One division of the joint cost is made on the ratio of the cost of a hypothetical system for fire protection only to the cost of that system plus the cost of a hypothetical system for general service only.

The "general service as an incremental cost method" assumes that fire protection is the primary function of the water supply system, and that only those charges not utilized by fire protection should be assigned to general service.

The "public fire protection as an incremental cost method" is the converse of the general service method; it assumes that public fire protection should be charged only with the incremental cost above the cost required for a general service plant.

The authors believe that the function of a water supply system is first to provide a safe and adequate supply of water for general consumption and that fire protection is an added benefit supplied by the water works system. On the basis of this premise, we believe the most equitable means of assessing fire protection charges is the method of "public fire protection as an incremental cost."

Studies of "Reasonable Return"

The first paper on fire protection rates published by the A.W.W.A. was by F. L. Fuller in 1888. Subsequently, many articles and discussions on the same subject have been published by the A.W.W.A. and other organizations. In order to bring some of the previous thinking more clearly into focus, and as a basis for comparison, we summarized the most important ideas on the subject before beginning our own analysis of the problem. This summary which was included in the original article (Wat. & Sew. Wks. Mar. 1955, p. 103) has been omitted here because of space limitations. It covered the Metcalf, Kuichling, and Hawley report of 1911, the Water Works Practice Manual of 1929, the Joint Committee Report of ASCE and ABA of 1951, and the AWWA Committee Report of 1954.

Discussion of Previous Studies

The most noteworthy idea of Metcalf, Kuichling and Hawley is the fundamental idea on which they base their reasoning: that the charge for fire protection should be an incremental or extra charge above the charge of supplying water for general consumption. To our knowledge, this idea was not questioned in the wide discussion following the paper. This concept appears to have been adopted by the water works industry, by Public Utility Commissions and Underwriters, and not until much later was doubt raised as to its validity.

The fundamental ideas represented by recommendations in the Manual of Water Works Practice are as follows: that the charges for fire protection service should be equal or related to the cost thereof; that for any water works system, construction cost is directly proportional to capacity; and that the allocation of cost between the two services, that is, fire protection and general consumption, should be in proportion to the ratio of the flows required for each service. The Manual made no effort to formulate the cost of fire protection service for an average water works system but, instead, recommended the procedures to follow and employed the data which are usually available for most water-supply systems.

The opinion of the Joint Committee that the consideration of the cost of fire protection as an incremental cost is not a fair and equitable practice seems unjustified. Much of the difficulty in obtaining equitable rates for fire protection service originated in the negotiations leading to the establishment of water works companies. The demand for water service was so strong that the consumers seldom made an effort to see that a just charge for fire protection service was distributed among the taxpaying population. As a result, many charges for fire protection service are much lower than the cost of furnishing that service. The older water works systems of this country were established

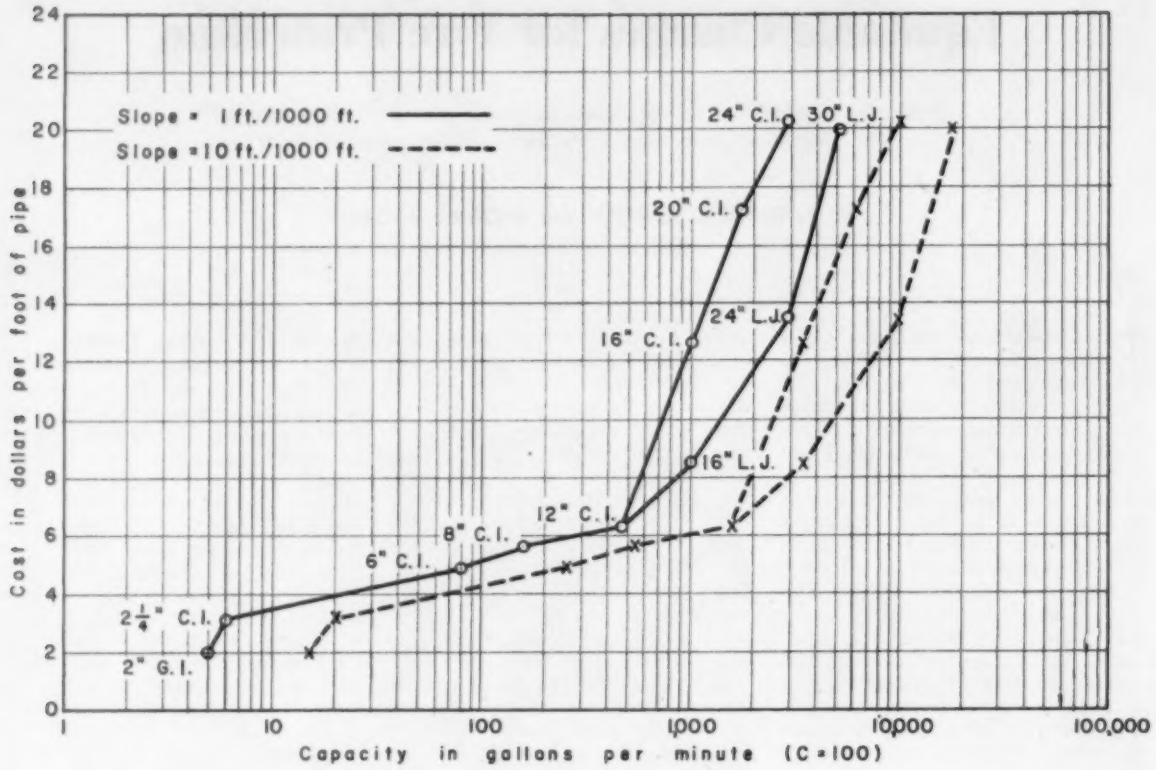

Fig. 1—DISTRIBUTION MAINS. Graphical relationship of cost to capacity.

for the primary purpose of furnishing water for general consumption. Thus, it would seem that the most equitable method of considering the cost of fire protection would be to assume that such costs are incremental.

An analysis of the three methods described by the Joint Committee ("General Service as an Incremental Cost," "Public Fire Protection as an Incremental Cost," and the "Capacity-Ratio Method") shows that there will be no differences in the share of the undivided fixed assets chargeable to fire protection—if the same flows are used for all three methods, and if costs are assumed to be in proportion to capacity, as was done by Metcalf, Kuichling and Hawley and also by the Joint Group in its development of the "Capacity-Ratio Method." If, however, costs are not assumed to be proportional to capacity and are actually estimated for the alternate systems in each method, it will be found that the first method ("General Service as an Incremental Cost"), gives the highest cost for fire protection, and the second method ("Public Fire Protection as an Incremental Cost"), gives the lowest cost. This is a very important conclusion, not recognized before, which probably has accounted for much of the confusion in thinking about equitable charges for fire protection.

Distribution System Costs vs. Capacity

At this point it becomes necessary to demonstrate that the cost of distribution mains is not proportional to their capacity, and that substantial errors result if cost is assumed proportional to capacity. The actual cost of distribution mains, per foot of length, constructed during 1950-'52 in the system of a large New England community has been plotted in Fig. 1 against capacity for hydraulic slopes of 1 and 10 ft. per 1000 ft. It will be noted that the actual cost varies at a rate considerably less than direct proportionality. For example, to double the capacity of a 6-inch pipe the cost is increased only 16 per cent (from $4.86 to $5.62 per ft.). Similarly a 2.86-fold increase in capacity is obtained in changing from 16-inch to 24-inch Lock Joint pipe, at an increase in cost of only 58 per cent.

The 1954 A.W.W.A. Committee report states that an accurate determination of the incremental cost of a distribution system chargeable to fire protection would require cost estimates based on two systems, one for fire only and the second with capacity both for fire and general service. Before accurate cost estimates could be prepared, a preliminary design of at least one of the two systems would be required. The high cost of this procedure has prevented its wide adoption. In general, this method is sound, but accurate determinations of cost are not possible by any method—primarily because of uncertainty as to the weight courts of law will give to calculations of original cost and reproduction cost.

The method of computing fire protection charges developed by our firm is an application of the A.W.W.A. method described above, modified to avoid the necessity of a preliminary design of a hypothetical system.

An alternative approach, suggested by the 1954 A.W.W.A. Committee to avoid the expensive procedure of making accurate cost estimates of two systems, involves the assumption that storage may be provided in lieu of capacity. This method is purely arbitrary, and has nothing to recom-

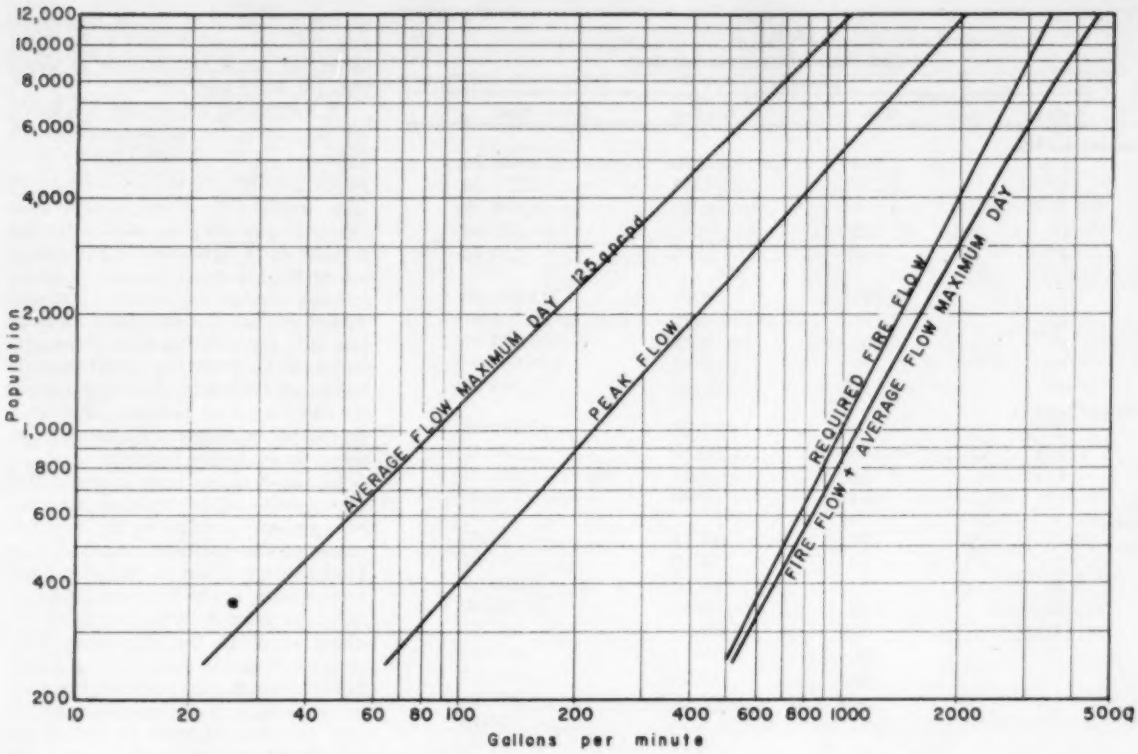

Fig. 2—MUNICIPAL WATER REQUIREMENT. Estimated present flows in terms of population served.

mend it. The cost of hypothetical storage bears no relation to the additional cost of a distribution system required to furnish public fire protection.

In its example, illustrating this alternative approach, the Committee adds to the cost of the hypothetical distribution storage the difference in cost of the distribution main based upon a 4-inch differential in pipe size. It is difficult to understand the reason for this procedure. It would seem either that the cost of the hypothetical distribution storage or the cost of the additional main capacity might be used, but not both. The adoption of a 4-inch differential in pipe size, to estimate the additional cost of the distribution mains for fire protection, is purely arbitrary.

The method used by our firm to estimate the difference in the cost of the two systems is based upon a differential in pipe size computed rationally from the flow requirements. As will be shown later, our figures indicate that a 4-inch differential is too great. Our studies show that in large cities the differential should not be charged to large distribution arteries, because the capacity requirement for peak hourly flow will exceed the capacity requirement for fire flow plus maximum daily flow.

Determination of Rates

In our consideration of the cost of furnishing public fire protection for a city with a population of 12,000, supplied by a private water company, the first step was to select methods to use in allocating cost between general consumption and fire protection. After study of the methods proposed by the various authorities who have considered this problem, it is our firm conviction that computing public fire protection as an incremental cost is the most equitable method.

Fundamental Principles Involved

In establishing rates to be charged by public utilities, the Smyth vs. Ames decision of the U. S. Supreme Court in 1898 is the basis of the law of the land. The legal principle set forth in this case is that utility owners are entitled to a fair rate of return upon the present fair value of the property used and useful in rendering the public service. In determining fair values, this decision maintained:

"In order to ascertain the fair value, original cost of construction, amount expended in permanent improvements, the amount and market value

TABLE 1
Sizes of Pipe Required
Hypothetical System Supplying Domestic Consumption Only

Population of Community	Q_2/Q_1 Peak Fire + Max. Day	$(Q_2/Q_1)^{\frac{1}{2.68}}$	Sizes in Present System							
			6"		8"		10"		12"	
			Req.	Use	Req.	Use	Req.	Use	Req.	Use
250	0.128	0.458	2.74	3						
500	0.161	0.500	3.00	3						
750	0.186	0.528	3.17	3	4.23	4				
1,000	0.208	0.551	3.31	4	4.40	6	5.51	6		
2,000	0.263	0.602			4.81	6	6.02	6	7.22	8
5,000	0.358	0.676					6.76	8	8.11	8
8,000	0.414	0.715							8.58	10
10,000	0.436	0.729								
12,000	0.470	0.750								
			Use 3"		Use 6"		Use 6"		Use 8"	

TABLE 2
Initial Cost of Distribution System
December 31, 1952

Size	Units	Unit Cost	Total
Cement-Lined Pipe			
12"	2,682'	$ 1.30	$ 3,486.60
10"	2,271'	1.00	2,271.00
8"	4,019'	0.85	3,416.15
6"	27,272'	0.72	19,635.84
4"	446'	0.65	289.90
Cast Iron Pipe			
12"	30,339'	6.99	211,999.35
10"	7,763'	4.91	38,116.61
8"	8,903'	3.95	35,139.07
6"	62,216'	2.33	144,664.01
4"	5,137'	1.16	5,939.59
Wrought Iron Pipe			
2"	44,413'	1.89	83,968.59
1½"	18,315'	0.72	13,160.38
1¼"	5,513'	1.03	5,662.71
1"	1,621'	0.94	1,519.31
Gates			
12"	67	112.33	7,525.90
10"	13	78.00	1,014.02
8"	23	68.11	1,566.57
6"	180	46.47	8,365.10
4"	10	20.56	205.55
2"	102	19.15	1,953.46
1½"	42	12.04	505.72
1¼"	16	13.27	212.24
1"	11	6.71	73.76
		Total December 31, 1952	$590,691.43

of its bonds and stocks, the present as compared with the original cost of construction, the probable earning capacity of the property under particular rates prescribed by statute, and the sum required to meet operating expenses, are all matters for consideration and are to be given such weight as may be just and right in each case. We do not say that there may not be other matters to be regarded in estimating the value of the property. But the company is entitled to ask a fair return upon the value of that which it employs for the public convenience. On the other hand, what the public is entitled to demand is that no more be exacted from it for the use of a public facility than the services rendered by it are reasonably worth."

The two limiting methods for determining fair value of property involved are: (1) the actual legitimate cost of the utility's property less depreciation, and (2) the present-day reproduction cost less the depreciation values based on the reproduction cost. There has been much controversy concerning relative weight which should be given to each of the above limits, in arriving at fair value of property under consideration.

In the example which follows, we have used both these limiting conditions to estimate the cost of fire protection. The rate for fire protection established under these assumptions is for public fire protection. The cost is directly assignable to the taxpayers of the city served by the water company; it is most feasibly charged directly to the city and paid for by the city. The cost is distributed to the taxpayers of the city by the normal taxing procedures.

Computations for Determining Rates

In this study, basic data used for making computations by the "Incremental Method" were obtained from the records of the water company. The water consumption data were taken from the company's daily meter readings. The maximum daily consumption during the past three years was as follows:

July 10, 1952.....1,470,000 gal.
July 8, 1951.....1,400,000 gal.
July 11, 1950.....1,446,000 gal.

For this study a maximum daily consumption of 1.5 mgd (million gallons per day) was used. No records were available of the peak consumption; this was estimated at 3 mgd, or approximately twice the average consumption on the maximum day.

In plotting the curves shown in Fig. 2 for maximum daily and peak domestic flows, the ratio of the peak flow to the average flow on the maximum day, was assumed to vary from about three for small populations to about two for large populations.

In estimating maximum fire flows, we have used the requirements of the National Board of Fire Underwriters as represented by the formula $Q = \sqrt{x}\ (1\text{-}0.01\sqrt{x})$ where Q is in gpm (gallons per minute) and x is the population in thousands. In instances where the fire requirements, as established in conformity with the National Board of Fire Underwriters' Bulletin No. 266, are different from those given by the formula, the actual requirements—correlated with the population of the city and portions thereof—should be used instead of the requirements given by the formula.

In our study we have assumed that the capacity of the existing distribution system is equal to the requirements of the National Board of Fire Underwriters; that is, that fire flows represented by the formula are available concurrently with a general demand equal to the maximum daily consumption. If the existing distribution system does not meet these requirements, it is not necessary to adjust the computations to reflect the deficiencies of the system. Since the result sought is the incremental cost of fire protection and this increment is obtained by deductions from the existing system, the increment will not be substantially changed by adjustments to reflect the inadequacies of the existing system.

In determining the per cent of the total value of the distribution system chargeable to fire flow, it is necessary to compare the cost of the existing system with the cost of a hypothetical system having no fire flow capacity. The standards of the N.B.F.U., which in our opinion are reasonable, require that the system be capable of delivering an adequate fire flow simultaneously with a normal draft equal to the maximum daily demand. We see no reason for assuming that the maximum fire flows will occur simultaneously with peak demand as has been assumed in some studies of this problem. Regardless of whether or not fire flow capacity is provided, a well-designed water works system must be capable of delivering a flow equal to the peak draft or peak hourly demand expected.

In comparing the existing distribution system consisting of pipes 6-in. and larger (pipes smaller than 6-in. are not adequate for fire protection and were assigned only to the distribution of domestic supply) against a hypothetical system for general service only, we have assumed that the

latter system requires capacities adequate to supply peak demands. In other words, we believe that the capacity in the system chargeable to fire protection is equal to the maximum daily demand plus the maximum fire flows minus the peak demands.

As an example: for a population of 250, the fire flow plus the maximum daily flow (see Fig. 2), is 520 gpm, and the peak flow is 65 gpm. The difference of 455 gpm, 87.5 per cent of the total, is chargeable to public fire protection. Similarly: for a population of 12,000, the fire flow plus maximum daily demand is 4,500 gpm and the peak flow is 2,080 gpm. The difference of 2,420, 53.8 per cent of the total, is chargeable to public fire protection. These additional capacities, large as they are, are to be charged for on the basis of the additional cost of the pipes.

The sizes of pipes required in the distribution system, for the hypothetical case of supplying domestic consumption only, were obtained by using the Hazen & Williams expression for flow in pipes. With any given hydraulic gradient and friction factor, the flow is proportional to the 2.63-power of the diameter, thus:

$$Q_2 = Q_1 \times (D_2/D_1)^{2.63}$$

From this formula a hypothetical pipe diameter D_2 can be determined which will give a flow capacity, Q_2, equal to a given per cent of the flow capacity, Q_1, in a corresponding pipe diameter, D_1 in the actual system.

The values of Q_2 and Q_1 for any population within the system may be taken from Fig. 1, where Q_2 is the peak flow and Q_1 is the maximum daily flow plus the fire flow. If it is assumed that any given pipe in the distribution system, 6 inches in diameter or larger, is adequate for providing fire flows plus maximum demand, then from Fig. 2 and the above formula the diamenter of the corresponding pipe in the hypothetical system may be computed.

Computation of Data

The results of computations as described above are presented in Table 1 for populations from 250 to 12,000. The ratios Q_2/Q_1 of peak demand to the sum of maximum daily and fire demand as shown in the second column were determined from Fig. 2. The headings of the last four columns show the pipe sizes in the existing system. Under each size of existing pipe and opposite a given population are two columns. The first column shows the theoretical pipe sizes required to supply peak flows only as computed from the equation. The second column shows the nearest standard pipe size sufficient to provide the peak flow only. This is a reasonable consideration, since in the final cost analysis it is reasonable to use only available pipe sizes. The pipe sizes for the hypothetical system have been computed only for populations which may reasonably be served by existings sizes at the head of each column. These limitations were determined by a study of the distribution system in question.

It will be noted from Table 1 that most of the existing 6-inch pipe would be replaced by 3-inch to produce the hypothetical system; most of the 8-inch by 6-inch; most of the 10-inch by 6-inch; and most of the 12-inch by 8-inch. In our computations to determine the cost of the hypothetical system, we have used the above replacement sizes. The sizes used are indicated at the botton of Table 1.

Table 2 gives the length, size and original cost of the distribution mains as of December 31, 1952. These figures are available in the records of most private water utilities, and should be available for a publicly owned water works.

The estimated difference in cost of a hypothetical system, which is capable of delivering the peak demand on the maximum day for domestic consumption only, and the actual system is given in Table 3. The sizes were obtained from Table 1 and the costs for those sizes were obtained from Table 2. Table 3 shows an incremental cost of the distribution system for fire protection of $211,866 based on original cost which is equivalent to 35.87 per cent of the total cost of the distribution system. This figure has been used to allocate the distribution system value as shown in Table 4.

TABLE 3

Incremental Cost of Distribution System for Fire Protection

Calculations based on Tables 1 and 2

Size	Price	Present System Length	Cost	Domestic Only Length	Cost
	Cement Pipe				
12"	$ 1.30 per ft	2,682 ft	$ 3,487		
10"	1.00	2,271	2,271		
8"	0.85	4,019	3,416	2,682 ft	$ 2,280
6"	0.72	27,272	19,636	6,290	4,529
4"	0.65				
3"	0.65*			27,272	17,727
	Cast Iron				
12"	6.99 per ft	30,339 ft	211,999		
10"	4.91	7,763	38,117		
8"	3.95	8,903	35,139	30,339 ft	119,839
6"	2.33	62,216	144,644	16,666	38,832
4"	1.16				
3"	1.16*			62,216	72,171
	Gates	**Number**		**Number**	
12"	112.33 each	67	7,526		
10"	78.00	13	1,014		
8"	68.11	23	1,567	67	4,563
6"	46.47	180	8,365	36	1,673
4"	20.56				
3"	20.56*			180	3,701
			$477,181		$265,315
			265,315		
	Incremental Cost for Fire Protection		$211,866		

*Prices for 3" hypothetical sizes assumed to be the same as the prices for existing 4" sizes.

Fixed Assets of System

The fixed assets of the water works were taken from figures prepared by the management. These are shown in Table 4. The allocation of these fixed assets is based upon the principle of incremental charges for fire service. In conformance with this principle, such items as the pumping station, electric pumps, transmission main, and reservoir were determined to be required by a system which would supply domestic consumption only under methods of operation now employed by the water works.

For example, one electric pump operating for approximately 10 hours will produce 1.5 mgd or approximately the maximum demand of the pres-

TABLE 4
Allocation of Fixed Assets on Basis of Initial Costs

	Total Account	Sub-Divisions	General Service %	General Service $	Fire %	Fire $	Undistributed %	Undistributed $
LAND	$ 6,983							
Power & Pumping		$3,025	100.00	$3,025				
Reservoir & Tank		3,958	79.38	3,142	20.62	$816		
STRUCTURES	114,643							
Source of Supply		2,112	100.00	2,112				
Pumping Station								
Pump Room		6,175	100.00	6,175				
Meter Room		5,575	100.00	5,575				
Heating System		1,499					100.00	$1,499
Reservoir		11,339	100.00	11,339				
Tank		65,891			100.00	65,891		
General & Miscellaneous Buildings		22,052					100.00	22,052
PRODUCTION EQUIPMENT	14,037							
Electric Pump		9,483	100.00	9,483				
Standby Pump		2,814			100.00	2,814		
Purification Equipment		1,740	100.00	1,740				
TRANSMISSION & DISTRIBUTION	799,675							
Transmission Mains		14,618	100.00	14,618				
Transmission to New Tank		3,846			100.00	3,846		
Distribution System		590,691	64.13	378,825	35.87	211,866		
Services		105,365	100.00	105,365				
Meters		54,575	100.00	54,575				
Hydrants		27,132			100.00	27,132		
Sprinkler Services (Private Fire Protection Only)		3,448						
GENERAL EQUIPMENT	21,633						100.00	21,633
MISCELLANEOUS PROPERTY	12,281						100.00	12,281
Total of Fixed Assets	$969,252							
Less Sprinkler Services	3,448							
Total Assets to be Distributed	$965,804			$595,974		$312,365		$57,465
Distribution of Undistributed				37,703		19,762		
				$633,677		$332,127		
Distribution of Costs			65.61%		34.39%			

ent consumers. Since pumping is done only during off-peak hours and is limited to approximately 10 hours, it was deemed necessary that a pump of this size would be required for domestic service only. The second pump would also be required for standby purposes. The 14-inch transmission main was found necessary to deliver deliver this quantity of water to the reservoir. The items applicable to fire protection only are hydrants, fire-service connections, the new elevated tank and the transmission main to the elevated tank, land for the elevated tank and the fire-protection share of the undistributed items.

Allocation to Three Classifications

The fixed assets, listed in Table 4 are allocated to three different classifications; namely, General Service, Fire and Undistributed. The assets allocated to Fire are those items used only in fire protection and are the new elevated tank, hydrants, and similar items. Certain items of fixed assets are not easily assignable to any classifications and are allocated to Undistributed. Such items are used in part by the other three classifications and consist of general equipment, miscellaneous property, buildings, etc.

After the assets are assigned to these various classifications they are totalled and the undistributed total is distributed between General Service and Fire in direct ratio of the total of each of these items to the total of these two items. After this distribution of the undistributed amounts, the percentage of the fixed assets under each heading is figured, and the percentages are listed at the bottom of Table 4. The final percentage of the fixed assets which is allocable to fire protection is 34.39 per cent.

Fire Protection Service Charge

The amounts of revenue derived from the fixed assets of the water works, as determined above, is assigned to fire protection in the percentage of 34.39. To this figure must be added the amount of operation and maintenance expense which is assignable to fire protection; it consists of items such as maintenance of hydrants and the fire protection portion of the undistributed overhead expense. In this example, the operation and maintenance expense chargeable to fire protection was determined to be 7.70 per cent. The total revenue chargeable to fire protection was then determined to be 24.42 per cent of the total revenues of the water company. The revenue figure (24.42 per cent) was based upon the book cost or actual out-of-pocket original cost.

A similar computation was made on the basis of present-day reproduction cost. A figure of 17.70 per cent of the revenues based on reproduction-cost method was arrived at. The actual fire-protection charges made in these instances were $34,500 for the example based on book cost, and $35,-

800 for the example based on reproduction cost. We recommended, therefore, an amount of $35,000 as the fair charge for fire protection service. It will be noted that, for this example, the fire protection charge was practically the same with book value and reproduction value. In most instances a wide divergence may be expected.

Rates Computed by Other Formulas

Let us now consider fire protection charges determined by other methods of computation. If we use the Metcalf, Kuichling and Hawley equation for a population of 12,000, the percentage of the total cost of the water works involved in fire protection is 56 per cent. The 56 per cent ratio corresponds with 34.39 per cent derived by our method. After the fire protection portion of the operation and maintenance cost has been added, the total percentage of revenue chargeable to fire protection is 36.2 per cent. This is in contrast to the 24.4 per cent by our method.

The capacity-ratio method, recommended by the Joint Committee of the American Society of Civil Engineers and the Section of Municipal Law of the American Bar Association, involves two procedures for figuring the ratio; one procedure is based on costs of systems, the other on capacities of systems.

In both procedures, two water works systems are considered, one to provide public fire protection only and one to provide general service only. In the first procedure, the jointly used facilities in the actual system are allocated between fire protection and other uses on the ratio of fire protection plant cost to the total cost of fire protection plant and general service plant. The other procedure is to make the allocation on the basis of the demand for water, the ratio in this case having as its numerator the maximum demand for fire protection, and as its denominator the demand for fire protection plus the maximum general service demand.

Using the costs of the distribution system developed for the incremental-cost method, it was possible to arrive at the cost of the distribution system for fire protection only, and the cost of a distribution system for fire protection only plus the cost of the distribution system for domestic service only. When this fraction was applied to the revenue to be derived from the fixed assets, and when the operation and maintenance expenses had been taken into account, it was determined that 35.9 per cent of the revenues for the water works should be derived from fire protection service. The same figure, using the demands of the fire protection system and the demands for the domestic system for determining the fraction, produced a percentage of the gross revenue of 35.5 per cent to be derived from fire protection. These figures are in contrast to the 24.4 per cent by our method.

Actual Charges Reported

A study of the "Survey of Operating Data for Water Works in 1950," a staff report published in the Journal of the American Water Works Association, indicated that for forty-six private water companies only one company had a percentage of total revenue derived from fire protection greater than 20 per cent. Only seven had a percentage greater than 10 per cent, and five derived no revenue for fire protection service. A similar analysis of the revenue from municipally owned water works undoubtedly would indicate a much smaller percentage of revenue being derived from fire protection service than is indicated for private water companies.

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SAFETY IN WATER AND SEWAGE PLANTS

BOTH THE AMERICAN Water Works Assn. and the Federation of Sewage and Industrial Wastes Assns. have published manuals on safety. The Federation's Manual of Practice was published in 1944; the AWWA Manual appeared in the Journal in 1955.

Need for Safety Program

Statistics gathered by the National Safety Council show that the water works industry has a higher rate of frequency of accidents than the gas, electrical or communications industries (in that order) and the severity rate is second highest. Data on sewage works has not been summarized but there is little reason to believe that the frequency of accidents is much less than in the water works industry.

Frequency is the number of disabling accidents per million man hours worked. In water works, data indicate the frequency rate to be 23.19 whereas in the communications industry it is 1.22. The severity rate (number of days lost per million man hours worked) is 930 in water works, while in the electrical industry it is 1550 and in the communications industry, 100. The fact that water and sewage plants employ relatively few men does not help the situation. National Safety Council data indicate that utilities with less than ten men have a frequency rate of 17.2 and a severity rate of 2700, the highest observed.

Causes and Costs of Inquiries

Handling objects is the source of more accidents than any other cause. This is followed by falls, falling objects, machinery, tools, etc. Injuries to the body lead the list, followed by injuries to the fingers, arms, hands, feet, head, eyes and lastly toes. toes.

Types of injuries occur in this order: bruises, contusions, cuts, lacerations, sprains, strains, fractures, burns and eye injuries.

The AWWA has shown that the cost of accidents are computable and occur in at least ten categories:

Time lost from work
Loss of future earning power
Economic loss to employee's family
Time lost by other workmen
Efficiency loss because of break up of crew
Time lost by supervisor
Cost of breaking in new employee
Damage to tools and equipment
Time damaged equipment is out of service
Spoiled work

These causes and costs of accidents are just as applicable in sewage and industrial waste treatment plants.

A Safety Program

The benefits to be gained from safety practices are many: improved efficiency, improved service, increased earnings, better employee morale, better public relations, and savings in the direct outlay for costs both by the utility and individual.

The AWWA Manual includes a section on how to set up a safety program and how to maintain it. The Federal Manual of Practice No. 1, likewise sets forth specific steps, and rules for a good safety program.

Steps to Prevent Accidents

1. Keep a record of all injuries, source, cause, result, cost, time lost, etc.
2. Make it a habit to look for hazards.
3. Correct any unsafe condition no matter where it exists.
4. Interest all employees in safety as an important factor in employer-employee relations.
5. Teach employees good work habits.

Safe Working Practices

The AWWA Manual contains 23 sections dealing with every possible operation or function in a water works and a full list of references on safety information.

The Federation Manual devoted most of its content to the prevention of dangers from noxious gases, vapors and oxygen deficiency and discusses how the prevention of physical injuries is related to design, safety equipment and safe practices. Information is organized under sections on sewers, pumping stations and treatment plants. Prevention of body infection is covered in relation to frequency of infection, plant design, safety equipment and safe practices.

References

The AWWA "Manual on Safety Practices for Water Utilities" may be obtained from the Amer. Water Works Assn., 2 Park Ave., New York 17, New York.

The Federation Manual of Practice No. 1, "Occupational Hazards in the Operation of Sewage Works" may be obtained from the Federation of Sewage and Industrial Wastes Assn., 4435 Wisconsin Ave., N. W., Washington 16, D. C.

A series of seven articles by LeRoy Van Kleech on "Safety in Sewage Works Maintenance and Operation" appeared in Water & Sewage Works between July 1953 and February 1954.

Safety in Chlorine Handling -- Gas Masks

by V. W. LANGWORTHY*
Development Engineer, Omega Machine Co., Providence, R. I.

ANY ARTICLE dealing with the subject of chlorine handling safety must devote attention to information regarding respiratory protective devices. This article will describe functions of the U.S. Bureau of Mines, general types of chlorine gas protective devices, their specific uses, and the limitations of each type.

Bureau of Mines

The Bureau of Mines of the United States Department of the Interior performs valuable services in connection with the promotion and use of safe, satisfactory and reliable respiratory-protective devices. To accomplish this broad program, the Bureau has established schedules of minimum requirements for the several types of breathing apparatus. Approval tests on self-contained breathing apparatus are conducted by the Safety Branch of the Bureau; tests on all other respiratory-protective devices are carried out by the Health Branch.

Equipment which has been submitted for approval and meets the Bureau's requirements is granted a certificate of approval, stating that the apparatus has passed the Schedule of Requirements and describing existing limitations. It should be noted that if approved devices purchased on the open market fail to pass prescribed tests, the approval certificate for the device may be rescinded.

Lists of approved devices are published periodically for the information of the public. A recent list was published as Bureau of Mines Information Circular 7636 dated June, 1952.

Types of Chlorine Gas Protective Devices

Devices classified as respiratory-protective include self-contained breathing apparatus, gas masks and supplied-air respirators.

All devices satisfactory for chlorine protection consist of a face mask connected either to an oxygen or air supply, or to a suitable canister which generates oxygen or to a canister capable of absorbing specific quantities of chlorine from the atmosphere.

The face mask is molded of flexible material and, when worn, is held in place by means of straps and friction clasps. *The mask must fit tightly*: allowing leakage of gas through or around the face mask is obviously courting disaster. Immediate rejection or repair is the only procedure when the face mask leaks.

Transparent ports in the face mask make vision possible. These ports vary widely in size and shape, and modern masks include circulation for fog prevention during use. Protective devices for use in a chlorine atmosphere should be restricted to those which include eye protection, due to the irritating nature of moist chlorine.

Provision for exhaust air is accom-

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M.S.A. Photo

Fig. 1—CHEMOX apparatus, an oxygen generating device
Maximum canister service is 45 minutes.

Scott Aviation Corp. Photo

Fig. 2—SCOTT AIR-PAK self-contained compressed air device
Maximum service of refillable cylinder is 30 minutes.

M.S.A. Photo

Fig. 3—M.S.A. self-contained demand type oxygen device Maximum service of refillable cylinder is 30 minutes.

M.S.A. Photo

Fig. 4—M.S.A. canister type chlorine service mask in use Gas concentration determines service of canister.

plished by various types of valving devices which remain tightly closed during the intake cycle of breathing.

Connections between the face mask and other parts of the apparatus utilize flexible tubes which permit free head movement. This tubing is resistant to crumpling and deterioration, and is vital to continued dependability of the mask; hence it should be subject to frequent critical inspection and testing for leaks.

Mask Inspection

Face masks and connecting tubing must be inspected regularly, certainly at intervals no longer than quarterly. The inspection should include visually examining all parts of the apparatus, then placing the mask upon the face, as in actual service.

To test for leaks, pinch off the corrugated connecting tube near the face-piece and inhale deeply. The face-piece must collapse completely to indicate airtightness of mask and tube connection. A similar procedure may be followed to check the condition of the connecting tube, by pinching the tube near the connection farthest from the face-piece and inhaling deeply.

In the event that leaks are found in either the face-piece, tube or tube connections, and if tightening of elastic straps and bolts does not prevent leakage, the only solution is to replace the complete face-piece with flexible tube attached. It is dangerous to take chances with a leaky gas mask, since a user will enter a contaminated atmosphere believing that he is protected against chlorine gas, only to inhale gas through the leaky parts of the device, with possible dire consequences.

Self-Contained Breathing Apparatus

As the name implies, a self-contained breathing apparatus is equipped with an oxygen or air supply as an integral part of the protective device. Use of this type of equipment is mandatory in working areas which are deficient in oxygen, or when a toxic gas exists in a concentration so high (above 2 per cent) that canister type masks are rendered useless.

The Bureau of Mines has issued certificates of approval for the following self-contained respiratory-protective devices (as of June 1, 1952):

Chemox oxygen breathing apparatus (¾-hour self-contained oxygen breathing apparatus). Approval BM-1307, issued to Mine Safety Appliances Co. October 3,1946. Cat. No. B-46328 Chemox Canister, Cat. No. B-45151.

Scott Air-Pak self-contained breathing apparatus (½-hour self-contained compressed air breathing apparatus). Approval BM-1308, issued to Scott Aviation Corp., October 3, 1946. Model 6000-A2M.

M.S.A. demand-type oxygen apparatus (½-hour self-contained compressed oxygen breathing apparatus). Approval BM-1309, issued to Mine Safety Appliances Co., October 3, 1946. Cat. No. B-45950. Oxygen cylinder, Cat. No. B-45153.

M.S.A. demand-type air apparatus (½-hour self-contained compressed-air breathing apparatus). Approval BM-1310, issued to Mine Safety Appliances Co., November 26, 1946. Cat. No. B-46307. Air cylinder, Cat. No. B-45843.

As will be noted from the above list, self-contained breathing apparatus operates for a specified length of time in an atmosphere deficient in oxygen, an important factor when high toxic gas concentrations exist. The time element is most important and the devices approved by the Bureau of Mines indicate service time remaining.

In the case of Chemox apparatus, a 45 minute timer may be set, with discard of a canister after use of any amount. The device may be tested for leaks by grasping the flexible in-

halation tube and inhaling deeply. Collapse of the face piece indicates sufficient tightness and proper functioning of the exhalation valve. Similar procedures are used to insure tightness of the inhalation valve and exhalation tube. The breathing bag may be checked by depressing both elbows firmly, if the bag does not deflate, the apparatus is tight.

The Chemox apparatus is an oxygen generating, canister-type device which utilizes the user's breath to activate an oxygen generating compound. This device is light weight (13½ lbs., complete) and has no high pressure cylinders, valves or fittings (see Fig. 1).

The Scott Air-Pak apparatus utilizes compressed air which is supplied to the user from a back-carried refillable cylinder, having 40 cu. ft. capacity, sufficient for 30 minutes use at extreme exertion. This device features a demand regulator which gives continuous indication of air supply remaining in the cylinder. The regulator is equipped with a radium dial and is located in full view of the wearer. Protection against regulator failure is afforded by an emergency by-pass valve which will allow a constant flow of air to the mask (see Fig. 2).

The M.S.A. demand-type devices each supply 30 minutes service, one utilizing compressed oxygen and the other compressed air. Both employ back-carried, refillable cylinders having 40 cu. ft. capacity, sufficient for 30 minutes use at extreme exertion (see Fig. 3).

The demand regulator continuously indicates the amount of service remaining and is located in full view of the wearer. The regulator may be by-passed in event of failure, providing a constant supply of air or oxygen to the face mask, with any excess air discharging through the exhalation valve or around the face mask.

Gas Masks—Canister Type

Canister type respiratory protective masks are used extensively in the sanitation field, with an admirable history of service. They are satisfactory for chlorine service when a gas concentration of two per cent (20,000 ppm) or less prevails in the atmosphere (see Fig. 4).

It should be emphasized that canister type gas masks can be used safely only when oxygen is present in life-supporting concentration. Canisters remove contaminants during inhalation—they do not supply oxygen: the decontaminated volume of air supplied to the respiratory system must contain sufficient oxygen or suffocation will result. The rupture of a chlorine package coincident with fire where an oxygen deficiency could occur, could create a situation requiring the use of either self-contained or supplied air respiratory-protective devices to combat the emergency effectively.

The life of the canister depends on the concentration of chlorine in the atmosphere. Effective service life may be several hours when exposed to very low concentrations of chlorine, but at high concentrations a canister may have a service life of only 15 minutes. At Detroit, for example, the *average* life of the canister is set at two hours.

Another limitation applies to canister type gas masks besides that of gas concentration. A common oversight among operating personnel is found in canister inventory, where seals have been removed to render masks instantly available for protection. Canisters, installed in the mask proper *with seals broken,* do not retain their chlorine absorptive capacity for an extended period and must be replaced immediately after use, or within one year, even though not used. Spare canister inventory should be stored with seals intact and dated so that rotation of new supplies is possible. Canisters older than four years are unreliable and must be rejected.

The Bureau of Mines has issued certificates of approval for canister type gas masks suitable for use in a chlorine contaminated atmosphere. Such approval is included under schedule 14, a schedule which is changed from time to time so that Bureau requirements keep pace with technical advancements. Following are the names and addresses of companies to which approvals have been granted (as of June 1952) as published in Bureau of Mines Information Circular 7636:

Acme Protection Equipment Co.
3037 West Lake St.
Chicago 12, Ill.

E. D. Bullard Co.
275 So. Eighth St.
San Francisco, Calif.

Davis Emergency Equipment Co.
45 Halleck St.
Newark 4, N. J.

Mine Safety Appliances Co.
Braddock, Thomas and Meade Sts.
Pittsburgh 8, Pa.

Willson Products, Inc.
Reading, Pa.

It is recommended that canister type masks be inspected *monthly* by checking the face mask and connecting tubing as mentioned earlier in this article. Operating personnel must be thoroughly acquainted with mask locations, spare canisters and mask inspection procedures.

Masks should be located immediately available to, but outside of, chlorine feeder and scale rooms, and the chlorine package storage area. Canister inventory should be so located that spares are easily accessible in a cool, dry place.

Supplied-Air Respirators
Hose Type Mask

Hose type masks supply air to the wearer through a length of hose and are available with or without hand operated blowers. It is apparent that such a respiratory protective device must provide clean breathable air, delivered from outside the contaminated area to the wearer, thus caution must be excercised when using this type equipment, which usually is available with 150 feet of hose (75 feet without blower).

The air hose is of large inside diameter, approximately 1", to enable a wearer to secure air through it in case of blower failure. Resistance to deterioration and crushing weights are factors considered in designing hose for supplied air respirators.

It is again pointed out that hose type masks require provision of clean breathable air to the wearer, limiting their use somewhat in chlorine contaminated atmosphere. They may be used to good advantage, however, in tank cleaning, underground repair work and in other confined spaces.

The Bureau of Mines approves hose masks with blowers for respiratory protection in any atmosphere regardless of degree of contamination or oxygen deficiency, providing clean breathable air can be reached within the permissable hose length. The Bureau of Mines covers this class of equipment in Approval Schedule No. 19.

Summary

Increasing attention to safety programs in the sanitation field provides opportunities to analyze hazards existing in our plants. A critical survey of the entire chlorine handling system is certainly in order at any time. While leaks in piping and other appurtenances cannot be predicted, it is possible to predict at all times the condition of protective devices and safety equipment.

Every employee should be trained in the use of protective devices he is expected to use under emergency conditions. Regular rehearsals, for example, which include the entire testing procedure and wearing of the equipment will increase the efficiency of an operator faced with circumstances requiring immediate action —*and may save his life.*

IV. FUNCTIONAL OPERATIONS

IN THE FIELD of sanitary engineering, there are several operations which are fundamentally the same for water, sewage, or industrial waste treatment works. These operations, which may be termed functional, include: Pumping, Electricity, Flow Measurement, Instrumentation and Control, Chemical Handling and Feeding, Coagulation and Sedimentation, Corrosion Control, Laboratory Control, and Maintenance.

Pumping

Liquid will move from one point to a lower point under the influence of gravity, but will not move in the reverse direction without energy being expended to move it. Gravity flow is utilized in sewers and in some water distribution systems, but in most water works, pumps are required to provide the pressure necessary to deliver the water to the consumer's tap.

In sewage works, pump lift sewage from one sewer to a higher one, or from an interceptor to a treatment plant at a higher elevation. Pumps are also used to lift water from wells and to pump air, chemical solutions, sludge, gas, etc. The design of a pump will depend on the material to be handled, suction lift, discharge head, operating conditions and efficiency desired.

Electrical Equipment Operation

Today, most pumps are operated by electrical motors. Electricity also operates instruments, controls, signals, communications, chemical feeders, and lighting systems. Electricity, and its potentialities and properties, is necessary to the operation of any water, sewage or waste treatment facility. Equally important are electrical motors which operate pumps and other equipment.

Flow Measurement

Where volumes of liquids or other substances are moved from one point to another, it is desirable to know, not to guess, the quantity of material handled. Reasons for flow measurement include: To provide data and information on plant production; to provide information on operation efficiency; to control unit operations; to ascertain quantity of water sold or volume of sewage treated; to determine costs of operation; and to provide permanent records of operation.

Points of flow measurement should be set up wherever measurement of volume in motion will produce information to satisfy any of the reasons for flow measurement. The more completely metered a water or sewage plant, the better and more efficiently it can be operated.

Instrumentation and Control

Instruments, sometimes called receivers or secondary instruments, are devices which indicate, record or totalize some function of operation which is being measured. Flow, levels, pressure, loss of head, temperature, etc., are conditions of operation which may be shown or recorded on a secondary instrument. Indicators show conditions at the moment of observations, recorders give a permanent and continuous record on a chart showing conditions as they existed at any moment. Totalizers give a numerical summation, to the moment of observation, of quantities in motion.

Closely coupled with instrumentation is the matter of control. Control of flow, control of chemical feeding dosage, control of filter operations, control of treatment operations are all essential to proper operation of water, sewage or waste treatment facility. Control can be obtained by the use of devices which operate in conjunction with or in direct response to flow measuring devices and their secondary instruments or in conjunction with other operating devices and instruments. The high cost and weaknesses of manual operating procedures can be greatly reduced by the use of instrumentation and control.

Chemical Handling and Feeding

Whenever water, sewage or wastes require chemical treatment of any kind, the plant operator is faced with the problems of handling and storage of chemicals, and with adding the proper amounts of chemicals to produce the treatment desired.

Chemical handling begins with the receipt of a shipment of chemicals and ends with the introduction of the chemical into a chemical feeder. Chemical feeding involves the operation of a device to add controlled amounts of the chemical to definite volumes of liquid. Control of chemical dosage according to the needs of treatment and flow to be treated is accomplished by chemical feeders designed for the purpose and controlled by a flow measuring device, or manually. Different types of chemical feeders are designed to feed solids, liquids or solutions, and gases. The selection of chemical feeders depends on a study of type of installation, treatment required, chemical used, dosage range, control, etc.

Coagulation and Sedimentation

Removal of suspended solids is necessary in surface water supplies, water softening operations. This operation involves sedimentation, which may take place in rectangular or circular tanks, usually equipped with mechanical devices for the removal of the settled material.

Design of sedimentation tanks is related to rate of flow, rate of settling of particles, detention times and facilities for removal of solids. Operation is controlled according to loading, both as to liquid and solid volume.

When solids in a liquid are too fine to settle easily by themselves (i.e., bacteria, colloids, etc.), chemicals may be added to create flocs which will settle and sweep out the fine particles. Coagulation is controled by analysis of the liquid and the proper dosage of the coagulating chemicals.

Corrosion Control

Since water is almost a universal solvent, its presence creates the problem of corrosion. Under certain conditions almost all metals will corrode or be attacked, as will concrete. In many cases corrosion may become a serious problem in water or sewage works. It can be controlled or prevented in various ways. The control may involve protective coatings, or chemical treatment of the liquid to reduce its corosive properties.

Laboratory Control and Maintenance

While the actual laboratory tests made in water plants may differ from those in a sewage works, the fundamentals of analytical chemistry and bacteriology are used in the operation of a control laboratory. Laboratory control can improve plant operations and the quality of the effluent, and often reduce costs of operation.

Maintenance, particularly preventive maintenance, reduces operating costs, improves efficiency and lengthens the life of equipment.

PUMPING PROBLEMS?

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BJ SUBMERSIBLES

Byron Jackson manufactures all three basics of a submersible... the PUMP... the SEAL... and the MOTOR... and combines them in BJ Submersibles and Subettes. Complete range of sizes and types. Capacities range from 30 to 20,000 gpm, and heads up to 1800 ft. BJ Submersibles can be applied to all deepwell problems.

BYRON JACKSON IS READY TO WORK WITH YOU ON YOUR PUMPING PROBLEMS...

1. **BJ supplies a *complete* line of centrifugal pumps and mechanical seals.**
2. **BJ can job-engineer any special pump to the required capacity, head, pressure and power.**
3. **BJ has competent sales engineers in 36 cities throughout the country.**
4. **BJ backs you by parts and service facilities of a long-established nation-wide organization (since 1872).**

BJ SUBMERSIBLE BOOSTER PUMPS

Complete pumping stations can be placed underground, under streets, parks, etc. Eliminate real estate investment and economically boost pressure for sub-division expansion, etc.

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BJ DEEPWELL TURBINE PUMPS

Bowl and impeller assemblies to meet every deepwell need. Standard models for wells 6", 8", to 24" dia., capacities to 9000 gpm, heads to 600 ft. "Bee Jay" models for 4", 5" and 6" dia. Choice of water or oil-lubrication.

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BJ LAKE AND RIVER INTAKE PUMPS

These pumps eliminate high or low water and icing problems on lake and river intake installations. Capacities to 20,000 gpm. Water-jacketed to operate in or out of water.

BJ BILTON PUMPS

General purpose pump with close-coupled motor pump unit. Mounts in any position. No rigid foundation needed. Ideal for portable service. Capacities to 2000 gpm, heads to 600 ft. Wide range of sizes.

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BJ HYDROPRESS PUMPS

Double-case pumps suitable for hydraulic press, boiler feed and descaling operations, other high-pressure, low-capacity water pumping requirements. Capacities to 500 gpm. Heads to 7000 ft.

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Single-stage pumps. For medium to high capacity jobs with low heads. Capacities to 50,000 gpm. Heads to 40 ft. For drainage, river-intake, dewatering, irrigation, etc. Easily adapted to special needs.

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Single or multi-stage. For pumping medium to high capacities of water. Two size ranges. Capacities to 50,000 gpm. Heads to 40 feet. Saves space, simplifies piping. For cooling tower, dewatering, drainage, river-intake and circulating.

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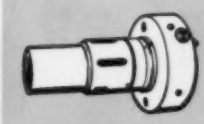

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PUMPS AND PUMPING

The subject of pumps and pumping is extremely important to the field of water and sewage works operations. Inasmuch as it is frequently necessary to move either water or sewage from one level to a higher one or cause the liquid to be discharged under pressure, it is necessary therefore that energy be expended on the liquid.

Electricity, steam, petroleum product combustion, or waterfall may be the source of power but the device which moves the liquid is a pump. A pump is a device which will receive a fluid from some source and discharge that fluid at a higher elevation or at a higher pressure.

The outline below covers the many phases of the subject of pumps and pumping.

A . . . Reasons for Pumping

1 . . Water
- a. To lift water
- b. To deliver water to consumers
- c. To supply fire pressure
- d. To move chemical solutions
- e. To back-wash filters
- f. To dewater tanks, basins, etc.

2 . . Sewage
- a. To lift sewage
- b. To move sludge
- c. To supply air
- d. To move gas
- e. To move chemical solutions
- f. To provide water supply

B . . . Types of Pumps

1 . . Classes by Operating Principles
- a. Displacement
  - (1) Reciprocating
    - (a) Piston
    - (b) Plunger
    - (c) Diaphragm
  - (2) Rotary
    - (a) Gear
    - (b) Lobe
    - (c) Moyno
    - (d) Sliding Vane
- b. Centrifugal
  - (1) Volute
  - (2) Diffuser
  - (3) Turbine
  - (4) Mixed Flow
  - (5) Propeller or Axial Flow
- c. Ejector or Jet
- d. Air Lift
- e. Hydraulic Ram
- f. Aorta

C . . . Applications

1 . . Low Service—Water
2 . . High Service—Water
3 . . Booster—Water
4 . . Deep Well
5 . . Boiler Feed
6 . . Chemical Feed
7 . . Sewage
8 . . Sludge
9 . . Air
10 . . Sump
11 . . Proportional Feeders

D . . . Selection of Pumps

1 . . General Considerations
- a. Application
- b. Source of Power
- c. Location
- d. Type of Pump

2 . . Specific Considerations
- a. Capacity and Number of Units
- b. Suction Conditions
- c. Discharge Conditions
- d. System Head
- e. Characteristics of Pump
- f. Service
- g. Economy

E . . . Operation Factors

1 . . Packing
2 . . Priming
3 . . Problems
4 . . Maintenance

F . . . Pumping Stations

1 . . Buildings
2 . . Location
3 . . Equipment

G . . . Pumping Terminology

1 . . Head
2 . . System
3 . . Centrifugal Pumps
4 . . Reciprocating Pumps

Individual articles which follow cover specific phases of the subject. More extensive articles on the subject have appeared in Water & Sewage Works in four series of articles.

Carter and Karassik—"Basic Factors in Centrifugal Pump Applications—Wat. & Sew. Wks.; 100: R-23 (May 1953)

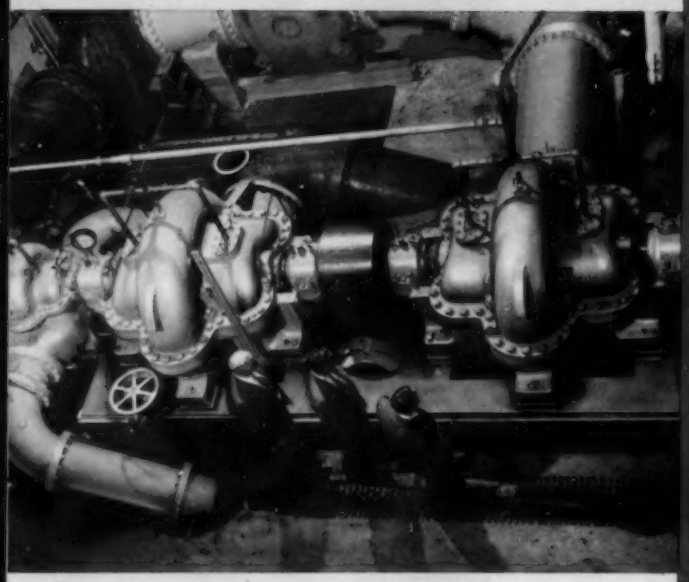
Caster and Karassik—"Basic Factors in Preparing a Centrifugal Pump Inquiry"—Wat. & Sew. Wks.; 100: R-50 (May 1953)

Carter and Karassik—"Designing, Constructing and Maintaining Centrifugal Pumps"—Parts 1-8 Wat. & Sew. Wks.; (1954-55)

Symons—"Pumps, Types and Principles"—Wat. & Sew. Wks.; 101:485 (1954)

Symons—"Pumps—Application and Operation"—Wat. & Sew. Wks.; 101:528 (1954)

ALLIS-CHALMERS



Milwaukee added 40 mgd to its pumping capacity by installing this 60-mgd Allis-Chalmers centrifugal unit in the space formerly occupied by one 20-mgd pumping engine. This new unit is driven by an Allis-Chalmers 3700-hp steam turbine and is also supplied with an A-C condenser.

Allis-Chalmers can supply a major percentage of the equipment needed for sewage plants, water works, municipal power plants, street and highway construction, and other public works. See the three following pages for further information on A-C equipment.

The record of Allis-Chalmers in building centrifugal pumps speaks for itself. Of thousands built, no A-C centrifugal pump has ever failed to meet its guaranteed efficiency. This means that when you specify Allis-Chalmers you are getting exactly what you intended to buy . . . exactly what you need.

Hundreds of cities . . . large and small . . . are already profiting from the efficiencies of Allis-Chalmers pumps. The range of types and capacities of A-C pumps will meet the needs of any city. There are special pumps for water supply, fire protection, sewage, and drainage. Sizes range from small compact units handling only a few gallons per minute to huge 72-inch pumps capable of handling 300,000 gpm.

Also worth while remembering is that you can get the entire pumping unit from Allis-Chalmers . . . for this company builds motors of every type, for operating every size of pump. You can also get the proper A-C starter for controlling the motor.

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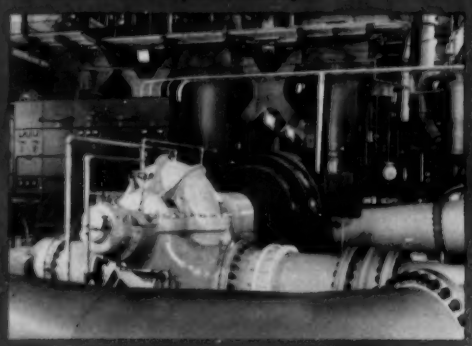
Builds

WORLD'S WIDEST RANGE OF PUBLIC WORKS EQUIPMENT

Three 16 by 14 inch single stage, double suction pumps with A-C cage motors in Hart Carolina plant.

These pumps are installed at a low level, with motors mounted above to prevent flooding.



Two new Allis-Chalmers 30-mgd pumps and their 3000-hp synchronous motors and controls were fitted into space formerly occupied by one 30-year-old, 15-mgd vertical pumping engine.

How to make
SEWAGE DISPOSAL
PAY!

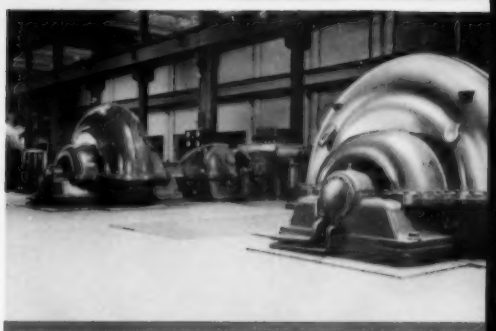
By-products can help pay part of sewage system expansion costs. Here's how...

The flow sheet at the right shows two modern treatment methods that use by-products to help meet expansion costs.

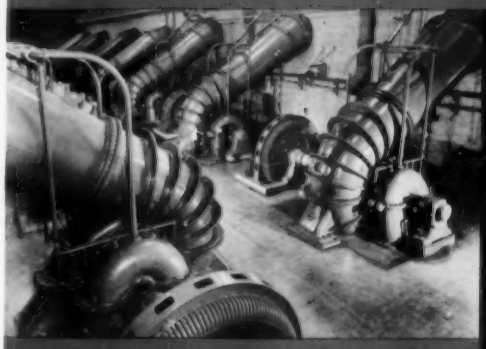
- Some cities, through the sale of fertilizer, are recovering a large percentage of the cost of operation.
- Other cities are using digester gas to supply most of the sewage power and light needs.
- Many industrial sewage plants are paying their way with similar improvements.
- The increasing use of home garbage disposal units is aiding many municipal plants to increase their by-product value.

Get Help on Your Problem

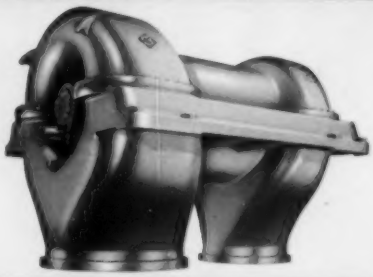
Allis-Chalmers, builders of the world's widest range of public works equipment, can help you analyze your problem and select the proper equipment for your particular needs. For complete information on any of the Allis-Chalmers items shown here . . . call your nearby Allis-Chalmers District Office or write Allis-Chalmers, Milwaukee 1, Wisconsin.



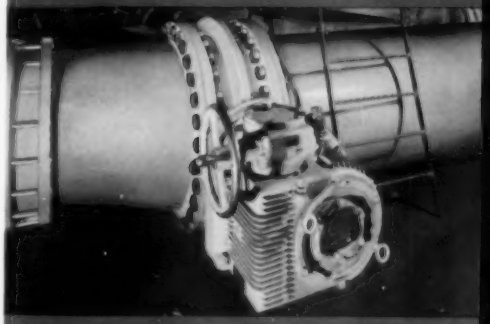
Three Allis-Chalmers 120,000-cfm turbo-blower units installed in plant of Sanitary District of Chicago.



Twelve 72-inch centrifugal pumps at the Racine Ave. Station Sanitary District of Chicago. They range in capacity from 375 to 500 cfs. They are driven by Allis-Chalmers synchronous motors, ranging in size from 1000 to 1750 hp.



A 200,000-cfm multi-stage axial compressor similar to this one is being furnished for the Chicago Sanitary District's West-Southwest Sewage Treatment Works. This A-C compressor will be driven by an 8250-hp Allis-Chalmers steam turbine.



Close-up of Allis-Chalmers butterfly valve. A-C builds many designs of valves, including units conforming to American Water Works Standards.

Allis-Chalmers 16 by 14-in. vertical sewage pump on combined storm and sanitary sewer main.

Some A-C Products for Sewage Works

CENTRIFUGAL PUMPS—Vertical or horizontal, for sewage and activated sludge.

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ROTARY VACUUM PUMPS—For use with vacuum filters in dewatering sludge.

ROTARY COMPRESSORS—For compressing digester gas.

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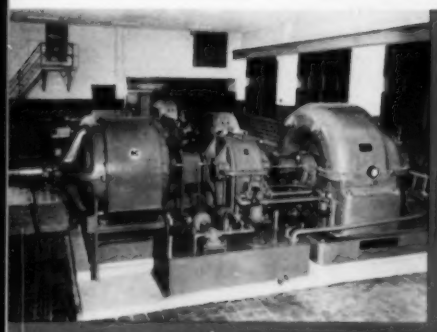
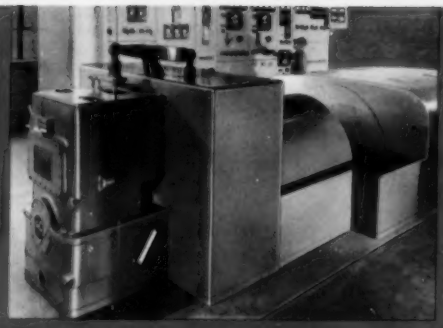
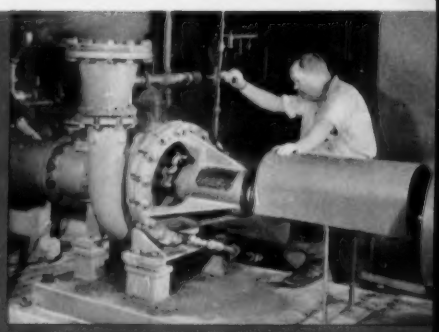
ELECTRICAL EQUIPMENT—Transformers, switchgear, circuit breakers, unit substations, generators, voltage regulators.



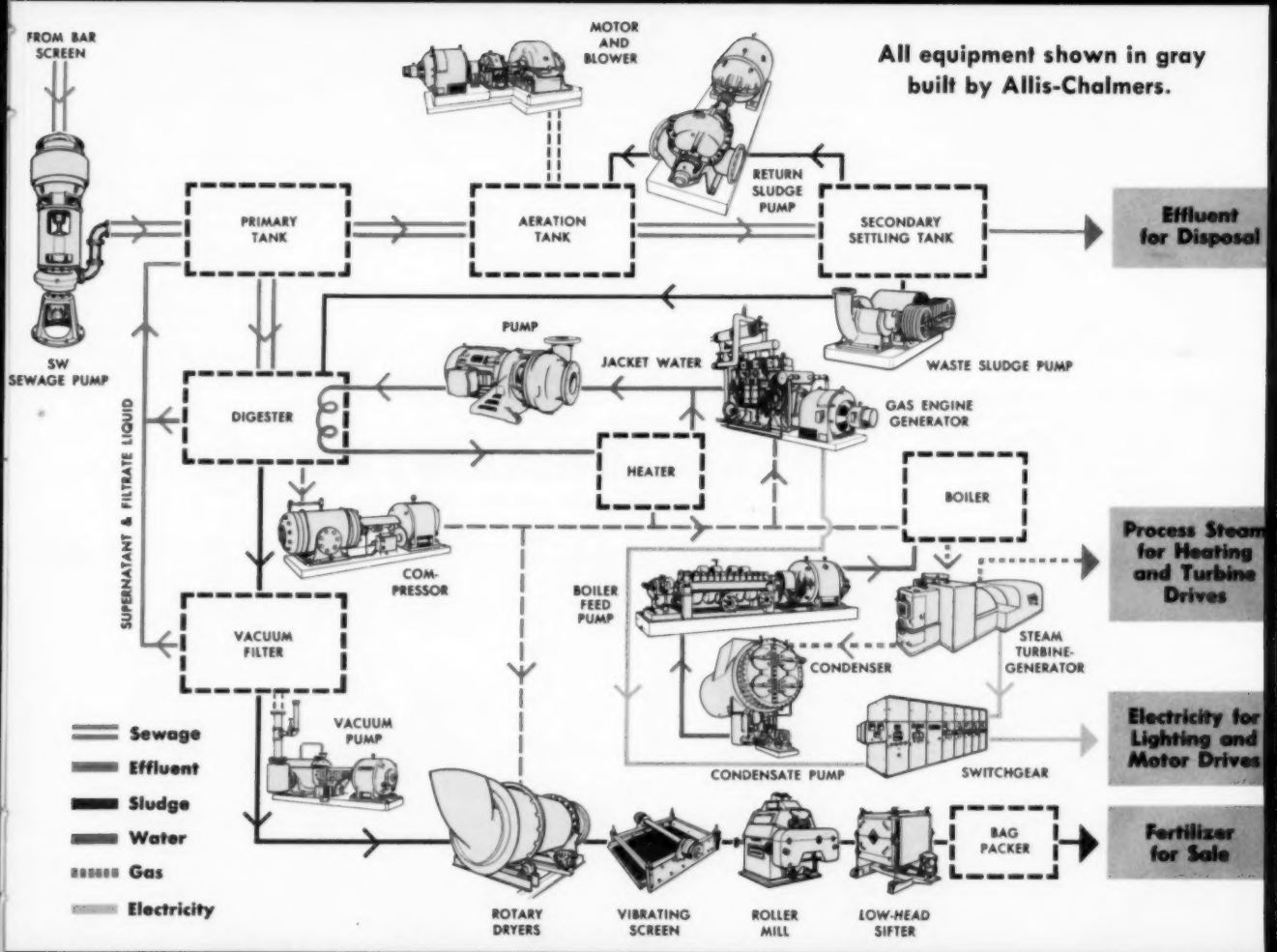
Three A-C blower units, 27,000 cfm, 10,000 cfm, 15,000 cfm.



A-C 2500-kw, 3600-rpm WA-Series steam turbine-generator unit with A-C switchgear in background.



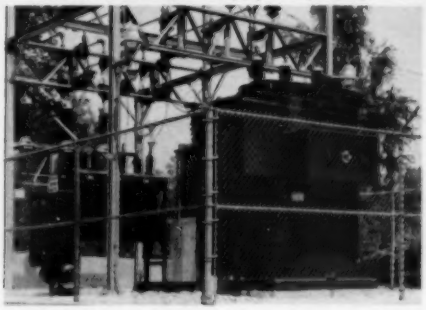
A-C sewage pumps have wide impeller openings, rounded impeller inlets to pass solids freely.



ALLIS-CHALMERS

← Rear view of 3000-kva, 4160-2400-volt unit substation with both incoming line section and distribution feeder section consisting of metal-clad switchgear.

Allis-Chalmers outdoor substation protects and controls the electrical power supply for a pumping station.



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Chlorextol is an Allis-Chalmers trademark.

Allis-Chalmers can supply a major percentage of all power generation, and electrical control and distribution equipment for public works. Included in the power generation line are steam turbine generator units, surface condensers, condenser and boiler feed pumps, water conditioning service and equipment.

The range of electrical products includes all types and sizes of motors from 1 hp to 100,000 hp and up, and starters or control to suit every application.

Allis-Chalmers indoor and outdoor high and low voltage switchgear provides maximum protection and flexible control of power distribution circuits. All units are metal enclosed, factory built, so they need only be bolted in place and lines connected. Switchboards are custom built to fill your needs.

A-C builds a complete line of power and distribution transformers. Most sizes can be cooled with either oil or *Chlorextol* non-inflammable liquid, or they can be of the air-cooled type.

Load center, single circuit and multi-circuit unit substations are built in standard ratings to meet every application. They are completely factory built and can be installed adjacent to equipment being served.

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Limiting Entering Head

How much a pump can pump

by R. A. MILLER

Application Engr., Cent. Pump Sect., Allis Chalmers, Mfg. Co., Milwaukee, Wis.

FOR THOSE who have experienced difficulty in expressing a pump's limitation in terms of *net positive suction head* (NPSH), perhaps the designation *limiting entering head* (LEH) may serve as a solution.

A pump can discharge only as much volume as it can receive. Limiting entering head is the measure for determining how much pumpable material can enter a pump, independent of its capability to produce discharge head or pressure.

The new designation of pump limitation, LEH, is original with Allis-Chalmers. The term is being used to minimize difficulties previously experienced in distinguishing between net positive suction head and the suction head itself. The suction head valve can be read on a gauge at the inlet of the pump, after the pump is primed but before it is operating. The limiting entering head valve cannot be read on a gauge (except in rare instances), but must be calculated.

Pump Capacity Considerations

The limiting entering head limits a pump's capacity or volume. The rpm and impeller diameter characteristics of a pump limit the head or pressure produced. In every pumping problem there are two LEH considerations: the required LEH of the pump and the available LEH of the installation site.

Pumping a liquid by displacement or by centrifugal force causes a lowered pressure at the pump inlet. New liquid will flow into this low pressure area if there is sufficient external force available to push it into the space as fast as it is being displaced. The measure of the external force required is termed the LEH of the pump.

Formula for LEH Value

A pump cannot move a liquid until the liquid enters the pump. LEH may be defined as the measure of the volume of liquid which can enter the pump. The formula may be given as:

Let Q = Volume of GPM
A = Inlet area of the pump
V = Velocity of the fluid
K = The pump designer's coefficient

Then $Q = AxVxK$

Since $V = \sqrt{2gh}$; therefore $Q = Ax\sqrt{2ghxK}$

K = A constant for a given pump

For a given size pump, the inlet area A is fixed and is a constant. 2g is also a constant, with g = pull of gravity (32.2).

Therefore, Q varies with "h"

"h" = LEH

"h" is the head of external force required to cause the desired volume, Q, to flow into the pump. Conversely, if "h" is fixed, it is the LEH, since it limits the quantity that can flow into the pump.

The formula is theoretical, and does not apply in actual practice due to design variations. Values must be determined from actual test. All pump curves have LEH (NPSH) designations plotted against volume in gpm. Therefore, it is unnecessary to calculate velocities or areas. It is necessary only to match the pump requirement with the available LEH. Somewhat more LEH value should be available than the minimum pump LEH requirement.

Effect of the Installation Site

Determine the elevation of the pump center line above or below the surface of the liquid entering head in feet.

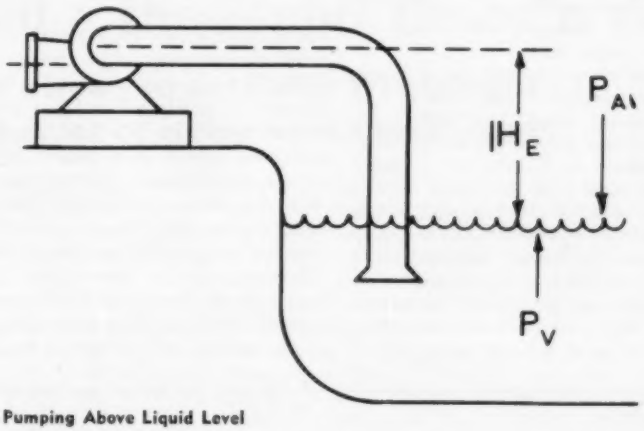
Determine the absolute pressure above the surface of the liquid PA converted to feet.

Determine the internal vapor pressure of the liquid due to temperature P_V converted to feet.

(PSI × 2.31) ÷ Sp. Gr. = feet

Then the available LEH = $(P_A - P_v) \pm H_E - H_F$

HF = Friction of suction piping, valves, screens, etc. in feet.



Pumping Above Liquid Level

Pumping water from a river, lake or reservoir at approximately sea level

$P_A = 34$ ft.

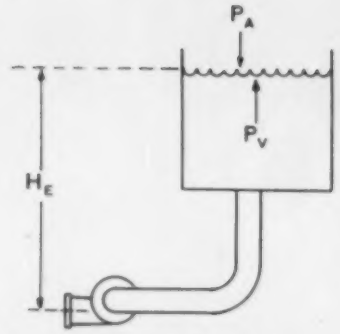
Water is 60°F $P_v = .6$ ft. $H_E = 10$ ft. Pipe friction 2 ft.

$LEH = (P_A - P_v) \pm H_E - H_F$

$= (34 - .6) - 10 - 2$

The available LEH = 21.4 ft.

For practical purposes the atmospheric pressure P_A will be reduced 1 ft for each 1000 ft elevation above sea level.



Pumping Below Liquid Level

Pumping water from a tank open to atmospheric pressure—elevation about 1000 ft above sea level.

$P_A = 33$ ft., water 160°F, $P_v = 11.2$ ft., $H_E = 12$ ft. Pipe friction $H_F = 2$ ft.

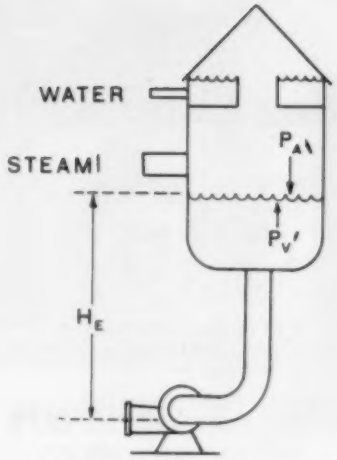
The available LEH = (33 — 11.2) + 12 — 2 = 31.8 ft.

If water temperature is increased to 212°F, $P_v = 33$, then the available LEH = 10 ft.

For other temperatures or liquids consult vapor charts.

Viscous fluids require corrections which can be obtained from charts.

Handling solids in suspension, paper stock, etc., requires special pumps and corresponding corrections from performance charts.



Pumping From Steam Pressure

Pumping water from a closed vessel or heater containing water subject to steam pressure. Water may be sprayed into the heater or cascaded in a series of waterfalls. The steam comes in intimate contact with the water and heats it to the same temperature as that of the incoming steam.

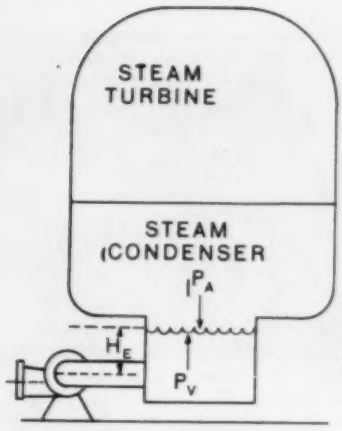
Steam 5 psig 227°F and $P_A = 19.7$ psia

Water in base of heater 227°F and $P_v = 19.7$ psia

$H_E = 37$ ft. $H_F = 2$ ft.

The available LEH = (19.7 psia — 19.7 psia) + 37 ft — 2 ft = 35 ft.

If the steam pressure is subject to sudden pressure drops, deduct the equivalent drop in feet from the available LEH before comparing with the minimum required LEH of the pump.



Pumping From Steam Condenser

A condensate pump removing water from a steam condenser. Because of construction and the expense of excavation, the hotwell is usually located just above the basement floor. H_E is very low, often only 2 or 3 ft and seldom over 5 ft. The condensate is at the saturation point. $P_v = P_A$ and H_F is negligible. The available LEH = $(P_A - P_v) + H_E - H_F$

LEH = 0 + H_E — 0; LEH = H_E

This H_E is often designated as "Sealing Head" or "Submergence."

Pumps with specially enlarged inlets are usually used for this service and extreme care must be taken in their selection because of the very low LEH. Cavitation and noisy operation are common occurrances because of lack of available LEH.

The above formula determines the difference in pressure between the state of the liquid and its boiling point, measured at the pump center line. It is known that when a liquid reaches the saturation point (boiling point) any further addition of heat or reduction in pressure will cause the liquid to vaporize.

It was stated earlier that a pump reduces pressure at the inlet due to the pumping action. The LEH value measures the limit to which the pump is permitted to reduce the pressure without vaporizing the liquid.

After determining the installation limitation, or available LEH, a pump can be selected to suit. Very often the installation LEH is very low, as with condensate pumps. Then, of necessity, a pump must be selected with a large inlet area, although it may operate at considerably less than the maximum efficient point of that pump.

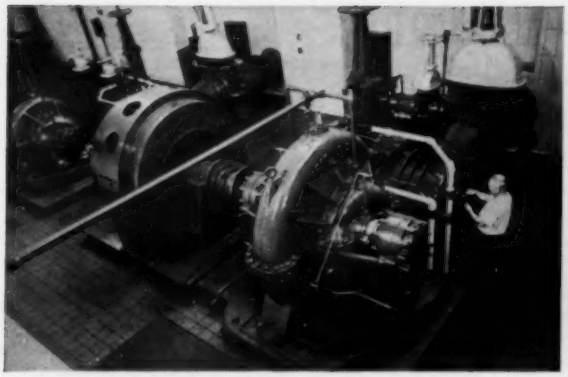
If the inlet area of a pump is increased to satisfy a low LEH condition, some efficiency will be lost. This condition results in a greater horsepower requirement. There exists a definite optimum relationship between inlet area, width, and diameter of an impeller, to produce maximum pump efficiency.

It often is economical to change the installation LEH to permit use of a more efficient and perhaps a less expensive pump.

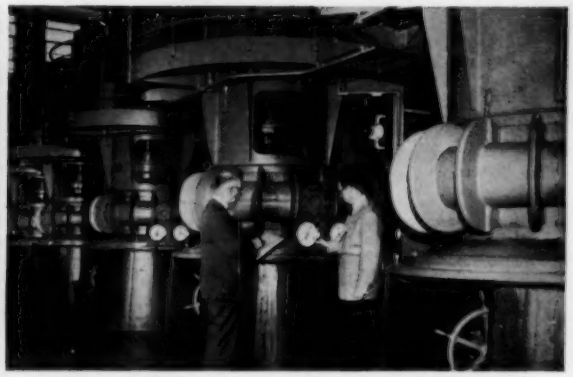
Be sure at all times that the installation LEH value is greater than the pump requirement, and that sufficient margin is allowed for sudden changes in the pressure on the surface of the liquid.

Practical Examples

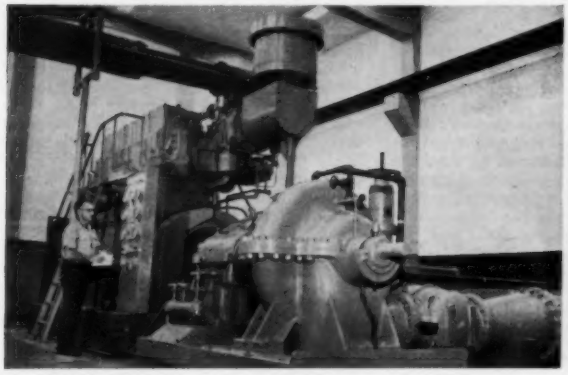
Four practical examples of how the LEH value can be applied to actual installations are illustrated. In each instance, calculations are given for the pumping conditions specified.



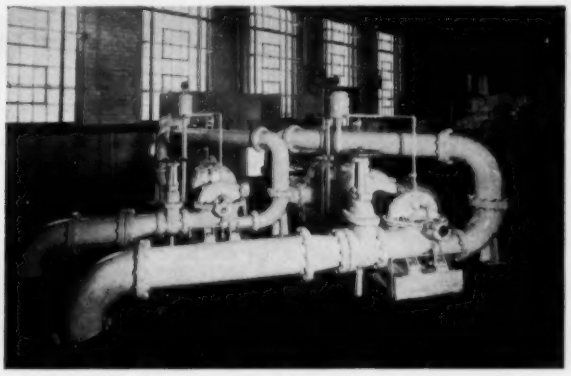
PHILADELPHIA, PA. One of ten Worthington high lift centrifugal pumps at the Torresdale Pumping Station. Capacity of this pump is 40 MGD.



NIAGARA FALLS, N. Y. Worthington high lift pumps in the Water Filtration Plant. In all, there are ten Worthington pumps, 15 to 30 MGD each.



MIAMI, FLA. One of four Worthington 15 MGD pumps driven by a Worthington diesel engine at the new Alexander Orr, Jr., Water Treatment Plant.



SHARON, PA. Two Worthington two-stage centrifugal pumps at the Sharon Valley Water Company. Capacity of the units is 2 MGD and 4 MGD each.

Reliability proved a thousand times a day

You benefit 3 ways when you deal with Worthington— world's leading builder of water works equipment

High output and low costs. Literally thousands of municipalities from the smallest to the largest have found that they get high volume output and low operating costs when they install water works equipment by Worthington. Every day, the reliability of this equipment is thoroughly proved in installations like those pictured here.

An unbiased recommendation. Because Worthington makes all types of pumps and drives, you get the advantage of an equipment recommendation based on a broad look at all available ways of doing the job. Trained specialists will help you analyze your requirements and select the proper equipment.

Unit responsibility. You do business with one company—eliminating delays and inconvenience that can occur when you are forced to co-ordinate the efforts of several suppliers. Unit responsibility by Worthington saves you time and money.

Some of the water works equipment built by Worthington include: horizontal and vertical centrifugal pumps; vertical turbine pumps; diesel, gas and dual fuel engines; steam turbines; speed increasing gears; and water meters.

For more information on any of these products, call your nearest Worthington District Office, or write Section W66, Worthington Corporation, Public Works Department, Harrison, N. J. In Canada: Worthington (Canada) 1955, Ltd., Toronto, Ont.

W.6.6

WORTHINGTON

ALL MAJOR PUBLIC WORKS EQUIPMENT UNDER ONE RESPONSIBILITY

Centrifugal Pumps

Notes on Selection of Pumps and Checking Pump Efficiencies

By H. E. BECKWITH
Engineer, The Pitometer Company, New York, N. Y.

TODAY the great majority of pumping stations are equipped with electrically driven centrifugal pumps, with an occasional Diesel driven or turbine driven centrifugal installation. The old slow moving reciprocating pump of yesterday could always be depended upon to take care of changing pumping loads and varying heads without any great loss in efficiency. But, this is decidedly not so with the modern centrifugal pump, designed to work under rather fixed conditions. Any appreciable variation from these conditions is accompanied by a falling off in efficiency, which may be rather marked.

Unfortunately, the non-technical water works operator who got his early practical experience with the old displacement type of pump has not always become sufficiently acquainted with the characteristics of the centrifugal pump. Only too often the only demand made on a centrifugal pump is that it pump water, and little or no attention is paid to the efficiency with which it does its work. In fact the average water works man is usually not acquainted with any simple method of determining this efficiency.

It is, therefore, the purpose of this article to point out the conditions which may be expected to cause low operating efficiency, and to outline a simple method for testing the wire-to-water efficiency which gives results as close as is necessary in practical water works operation.

Basic Principles of the Centrifugal

As a youngster I used to tie a chestnut on the end of a string and whirl it around my head until I had imparted to it the force necessary to take it flying through the air at high speed. You did it, too. The principle of building up velocity of that chestnut by whirling it about the head is the same principle which is used in the design of a centrifugal pump. The water which enters the pump through the suction inlet is seized by the rotating vanes of the impeller and spun until it is rotating at terrific velocity. Since pressure and not velocity is desired, the pump is so designed that by gradually slowing down this velocity in the casing of the pump, the energy stored up in this rapidly moving water is almost entirely changed to pressure. The speed of the chestnut rests upon two factors—the length of the string and the number of revolutions made within a specified period of time. The speed, and hence the resulting pressure, imparted to water by a centrifugal pump also rests upon the same two factors—the diameter of the impeller and the number of revolutions per minute which the impeller makes.

There are, of course, practical limits to both the speed and the diameter so that it is not always possible to secure the full desired pressure with one pump. If not, the water is passed through two or more pumps in series, and each pump raises the pressure part of the total desired amount. Sometimes these two or more pumps are built in one pump case, in which instance each pump is called a "stage." Since electrically driven centrifugal pumps operate at fixed speeds, there is always one head under which a pump will operate most efficiently. Right here it will not hurt to repeat that any material deviation from this condition will result in decreased efficiency.

Pump Performance Curves

At this point I want to introduce a typical centrifugal pump curve which we will use for illustration during this discussion. Similar curves are available from the manufacturer for all medium sized and large pumps. On small pumps it is not customary to furnish such performance curves.

It will be noted from an inspection of the specimen curve that the greatest efficiency for this particular pump (about 75 per cent) is secured when the head is about 155 ft. and the discharge rate is about 1,300 gpm. You will also note that as the head is materially increased or decreased from the optimum head there is a large change in the pumping rate and a considerable drop in efficiency. A great deal has been done in design effort to widen out the "peak" of the efficiency curve into a "plateau" so as to give high efficiencies for centrifugal pumps under a wider range of operating conditions. Considerable progress has been made in this direction.

Friction Head—Its Importance

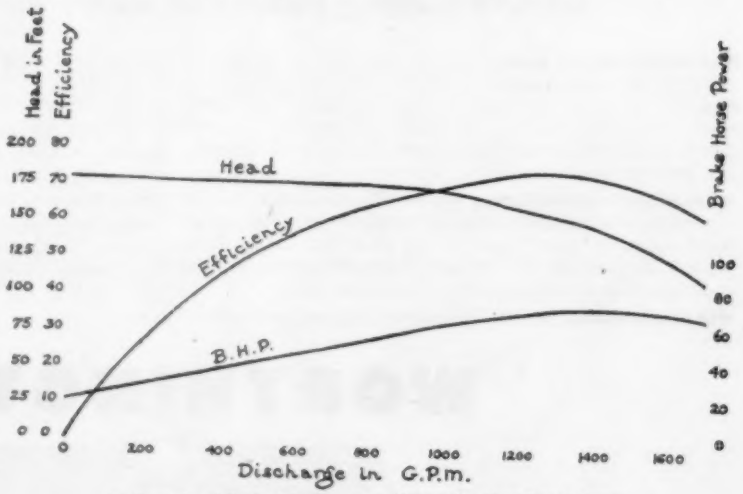
Let us see what happens when we forget to include pipe friction loss when figuring the total head against which the pump must operate. If we have figured on the pump whose curve we have, and if we are pumping through two miles of 16 in. main, the friction loss will add about 18 ft. to the pumping head—making it 173 ft. At this head (see curves) the pumping rate will drop to 1,000 gpm. and the efficiency to 70 per cent. Furthermore, the pump is operating on a very critical part of the curve where a slight increase in pumping head—caused by tuberculation in the main or by any other reason—would incur a precipitate drop in both the efficiency and the pumping rate. It also illustrates what can happen to a pump, after installation, when the pumping head has been increased above the head for which it was designed. As it is the nature of unlined iron and steel mains to tuberculate, resulting in a constantly rising friction loss, this is an important consideration.

Let us illustrate this in another way.

Selecting the Right Pump

Suppose that we are in the market for a 1,000 gpm. pump operating against a total head of 173 ft., and a pump whose curve we have been using has been submitted for consideration. I would not consider this pump a good "buy" to operate under these conditions. In the first place it will be noted that the efficiency of 70 per cent is much below the maximum efficiency of 75 per cent. But even more important, perhaps, is the fact that the pump at 173 ft. head is operating under "critical head" conditions. An increase of only about 8 ft. (less than 5 per cent) in the pumping head would bring the head to the maximum which the pump can create—in other words to the "cut off" point. This means that an increase in the head of only 8 ft. (about 3½ pounds) would decrease the pumping rate from 1,000 gpm. to zero gpm. Moreover an increase of only 3 ft. in head would cause a drop of 200 gpm. in the pumping rate. On the other hand, when we are working in the most efficient range of the pump a change of 3 ft. in the head would only cause a variation of 30 to 40 gpm. in the pumping rate; and, the efficiency is practically unaffected.

It follows, therefore, that one should buy a pump within the range where the efficiency curve is as *flat* as possible and the head curve is as *steep* as possible. In this connection a word of warning may not be amiss. By making the vertical scale of the



An Example of Typical Performance Curves for Centrifugal Pumps. Various designs show individual characteristics in respect to the curves produced.

Mr. Beckwith's article is based on a paper presented before the Penna. Water Operators Assn. and includes material from an earlier Reference and Data article by the author.

curve less than is customary, a much flatter *appearing* efficiency curve can be secured. So in comparing the performance curves of pumps be sure that they are plotted on comparable scales. I have known curves with reduced vertical scales to be submitted where I felt sure that the scale was deliberately reduced for the purpose of deception.

Mistaken Economy

Only too often in the revamping of a plant, efforts are made to re-use as much of the old equipment as possible. It may be assumed that if the old pump will handle 1,300 gpm. against 155 ft. of head it should have less trouble pumping the same amount from the river to the settling basin against a head of only forty or fifty feet. This is so. In fact, if we will look at the curve we will find it will pump more than 1,300 gpm. at the lower head. The curve does not go out that far, but it goes far enough to show what would happen—not only to the pumping rate but to the efficiency as well. The pumping *rate goes up* but the *efficiency goes down*—yes, way down. Reducing the head has a tendency to cause a pump to run away much as an automobile would run away down hill when the going becomes easier if the throttle were not closed to compensate for the decreased demand for power. This running away of the pump sometimes overloads the motor so that it runs hot. To prevent this, operators raise the head artificially by partly closing a valve on the outlet side of the pump. This decreases the load on the motor and brings the pumping rate back to normal. But it burns up a great deal of power needlessly as the closed valve destroys part of the head generated by the pump and only part of the work actually performed is effective. I have known of installations, such as this, where the installation of a new pump saved more than enough power in one year to pay the entire cost of the new pump and motor and also completely depreciate the old unit replaced.

But it is not always necessary to buy a new pump just because the head has been reduced. If we will get back to that chestnut on the string we will find that we can reduce the speed of the chestnut by reducing the length of the string, at the same time keeping the number of revolutions constant. In the same manner, we can cut down the pressure generated by a constant speed centrifugal pump by reducing the diameter of the runner. If the reduction in head is moderate, the manufacturer can advise you how much will have to be machined off the outside of the present impeller so that it will pump efficiently, or at a slight expense he will furnish a new impeller for the changed conditions. Or he may cut down your old impeller.

It is sometimes possible to secure a larger impeller to efficiently handle increased heads, but in this case the motor is likely to be overloaded unless the original specification anticipated such change as loads increased.

Another way to increase the speed of that chestnut would be to keep the length of the string constant and to increase the number of revolutions. It follows that if we increase the revolutions of any centrifugal pump we will increase the head which that pump will generate. This explains why a certain pump tested last fall gave a wire to water efficiency of only 40 per cent. This pump was designed for use with a gasoline motor and to operate under the then existing head conditions at a speed of 1400 rpm. Eventually electric power became available and the pump was connected to an electric motor and the speed increased to 1,800 rpm. This, of course, increased the head generated by the pump itself, and the efficiency was consequently very low.

A somewhat similar condition was found several years ago when a 5 mgd. installation designed to work against a head of 100 pounds was found to have been connected in series to a 5 mgd. pump designed to pump against 50 pounds pressure. This gave an installation with a design head of 150 pounds, but the actual head was still only about 100 pounds. The *output* was thereby *increased* to approximately 6 mgd. but the *efficiency decreased* to the point where it was only slightly above 40 per cent. New and properly designed equipment brought the wire-to-water efficiency up to about 75 per cent.

It can be readily seen from the above considerations that the chances of buying a suitable pump from the "junk man" are just about nil. It might be "as good as new" for the conditions for which it was designed and yet be absoluately worthless under any other conditions. In fact, it would probably be a most expensive liability. Yet pumps have been bought from the equivalent of "junk men", but most frequently have been "salvaged" by the original purchaser for other duty than originally purchased for.

So far, we have been discussing equipment which has been working under conditions which made it impossible to give a creditable showing. A mere inspection of the conditions and a knowledge of the design limitations would make it evident that satisfactory performance under these conditions could not be secured. However, there are occasions where, after installation, things happen to properly selected pumps which will cut the efficiency of the equipment. There was, for instance, the time when we found a water snake wrapped

Table I—Gallons of Water Delivered per Kilowatt Hour Against Various Heads on Theoretical Assumption That Pump and Motor Are 100 Per Cent Efficient

H = head in feet. G = gallons per kilowatt hour

H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G
1	318,200	51	6,240	101	3,151	151	2,108	201	1,583	251	1,268	301	1,058	351	907	401	794	451	706
2	159,100	52	6,120	102	3,120	152	2,094	202	1,575	252	1,263	302	1,054	352	904	402	792	452	704
3	106,100	53	6,005	103	3,090	153	2,080	203	1,567	253	1,258	303	1,051	353	902	403	790	453	703
4	79,560	54	5,894	104	3,060	154	2,007	204	1,560	254	1,253	304	1,047	354	899	404	788	454	701
5	63,650	55	5,786	105	3,031	155	2,053	205	1,552	255	1,248	305	1,044	355	897	405	786	455	700
6	53,040	56	5,683	106	3,002	156	2,040	206	1,545	256	1,243	306	1,040	356	894	406	784	456	698
7	45,460	57	5,583	107	2,974	157	2,027	207	1,537	257	1,239	307	1,037	357	892	407	782	457	697
8	39,780	58	5,487	108	2,947	158	2,014	208	1,530	258	1,234	308	1,033	358	889	408	780	458	695
9	35,360	59	5,394	109	2,920	159	2,002	209	1,523	259	1,229	309	1,030	359	887	409	778	459	694
10	31,830	60	5,304	110	2,893	160	1,989	210	1,516	260	1,224	310	1,027	360	884	410	776	460	692
11	28,930	61	5,217	111	2,867	161	1,977	211	1,508	261	1,220	311	1,024	361	882	411	775	461	691
12	26,520	62	5,133	112	2,842	162	1,965	212	1,501	262	1,215	312	1,020	362	879	412	773	462	689
13	24,480	63	5,051	113	2,816	163	1,952	213	1,494	263	1,211	313	1,017	363	877	413	771	463	687
14	22,730	64	4,972	114	2,794	164	1,940	214	1,487	264	1,206	314	1,014	364	875	414	769	464	686
15	21,220	65	4,896	115	2,766	165	1,929	215	1,480	265	1,202	315	1,011	365	873	415	767	465	685
16	19,890	66	4,822	116	2,744	166	1,917	216	1,474	266	1,197	316	1,007	366	870	416	765	466	683
17	18,720	67	4,750	117	2,720	167	1,906	217	1,467	267	1,193	317	1,004	367	868	417	763	467	682
18	17,680	68	4,680	118	2,697	168	1,894	218	1,460	268	1,188	318	1,001	368	865	418	761	468	680
19	16,750	69	4,611	119	2,674	169	1,883	219	1,453	269	1,184	319	998	369	863	419	760	469	679
20	15,910	70	4,547	120	2,652	170	1,872	220	1,447	270	1,179	320	995	370	860	420	758	470	677
21	15,150	71	4,482	121	2,630	171	1,861	221	1,440	271	1,175	321	992	371	858	421	756	471	676
22	14,470	72	4,420	122	2,609	172	1,851	222	1,434	272	1,170	322	989	372	856	422	754	472	675
23	13,830	73	4,360	123	2,588	173	1,840	223	1,427	273	1,168	323	986	373	854	423	753	473	674
24	13,260	74	4,301	124	2,567	174	1,829	224	1,421	274	1,162	324	982	374	851	424	751	474	672
25	12,730	75	4,243	125	2,546	175	1,819	225	1,414	275	1,158	325	979	375	849	425	749	475	671
26	12,240	76	4,188	126	2,526	176	1,809	226	1,408	276	1,154	326	976	376	847	426	747	476	669
27	11,790	77	4,133	127	2,506	177	1,798	227	1,402	277	1,150	327	973	377	845	427	746	477	668
28	11,370	78	4,080	128	2,486	178	1,788	228	1,396	278	1,146	328	970	378	842	428	744	478	666
29	10,970	79	4,028	129	2,467	179	1,778	229	1,390	279	1,142	329	968	379	840	429	742	479	665
30	10,610	80	3,978	130	2,448	180	1,768	230	1,384	280	1,137	330	965	380	838	430	740	480	663
31	10,270	81	3,929	131	2,429	181	1,758	231	1,378	281	1,133	331	962	381	836	431	739	481	662
32	9,945	82	3,882	132	2,411	182	1,749	232	1,372	282	1,129	332	959	382	833	432	737	482	660
33	9,644	83	3,834	133	2,393	183	1,739	233	1,366	283	1,125	333	956	383	831	433	736	483	659
34	9,360	84	3,789	134	2,375	184	1,729	234	1,360	284	1,121	334	953	384	829	434	734	484	658
35	9,093	85	3,744	135	2,358	185	1,720	235	1,354	285	1,117	335	950	385	827	435	732	485	657
36	8,840	86	3,701	136	2,340	186	1,711	236	1,349	286	1,113	336	947	386	825	436	730	486	655
37	8,601	87	3,658	137	2,323	187	1,702	237	1,343	287	1,109	337	945	387	823	437	729	487	654
38	8,375	88	3,617	138	2,306	188	1,693	238	1,337	288	1,105	338	942	388	820	438	727	488	652
39	8,160	89	3,576	139	2,292	189	1,684	239	1,332	289	1,102	339	939	389	818	439	725	489	651
40	7,956	90	3,536	140	2,274	190	1,675	240	1,326	290	1,098	340	936	390	816	440	723	490	650
41	7,762	91	3,497	141	2,257	191	1,666	241	1,320	291	1,094	341	934	391	814	441	722	491	649
42	7,577	92	3,458	142	2,241	192	1,658	242	1,315	292	1,090	342	931	392	812	442	720	492	647
43	7,401	93	3,422	143	2,225	193	1,649	243	1,310	293	1,087	343	929	393	810	443	719	493	646
44	7,233	94	3,386	144	2,210	194	1,640	244	1,304	294	1,083	344	926	394	807	444	717	494	644
45	7,072	95	3,350	145	2,195	195	1,632	245	1,299	295	1,079	345	923	395	805	445	716	495	643
46	6,916	96	3,315	146	2,180	196	1,624	246	1,294	296	1,075	346	920	396	804	446	714	496	642
47	6,771	97	3,281	147	2,165	197	1,615	247	1,288	297	1,072	347	918	397	802	447	712	497	641
48	6,630	98	3,248	148	2,150	198	1,608	248	1,284	298	1,068	348	915	398	800	448	710	498	639
49	6,495	99	3,215	149	2,136	199	1,600	249	1,278	299	1,065	349	913	399	798	449	709	499	638
50	6,365	100	3,183	150	2,122	200	1,592	250	1,272	300	1,061	350	910	400	796	450	707	500	636

around the shaft with the result that the inlet ports were partially cut off and the suction lift increased way beyond the 15 feet maximum for best performance. In another and similar situation blocks of wood were found jammed in the ports. Then there was the time that low efficiency was caused by the blowing of the gasket of a multiple stage pump and the water was short circuiting back from a higher stage to a lower stage. One of our engineers once reported that an efficiency of 20 per cent was caused by the impeller slipping on the shaft.

Two interesting conditions have been found by the author which have no reference to the actual efficiency of the pumps but which were determined as the result of making efficiency tests. In one instance, where the meter through which power was purchased was used to measure the power input, it was found that an apparent low efficiency was caused by this meter being set 20 per cent high. In another instance, a pump was discharging into a closed distribution system. On the basis of the water *actually discharged* into the system (24-hour period) the pump had an efficiency of only 8 per cent. Had a standpipe or reservoir been floating on this system, the same amount of water could have been pumped with about one-eighth the amount of power which was actually used.

So much for the reasons why efficiency tests should be made at intervals.

A Simple Efficiency Test

The writer has worked out a simple method for making efficiency tests which he has been using with satisfactory results for some years.

At one foot of head and 100 per cent efficiency of *both pump and motor* it is theoretically possible to raise 318,200 gallons of water one foot with one kwh. To determine this theoretical value for any other head, simply divide 318,200 by the head involved. For instance,

$$\text{the value at 159 ft. would be } \frac{318{,}200}{159} = 2{,}001.2 \text{ gal.}$$

per kwh. In this connection the accompanying table may prove helpful in reducing calculations in pump testing.

To determine the *wire-to-water efficiency* of an installation it is only necessary to divide the actual pumpage per kwh by the theoretical value for the pumping head, as determined from the table. A rough check can be made by dividing the month's pumpage in gallons by the kwh consumed. This gives the gallons actually pumped per kwh.

Test Procedure

With the pump running, determine the total head in feet (including suction) against which the pump works. Divide 318,200 gallons by this total head (as above) to determine the theoretical 100 per cent pumpage per kwh. (Or take the figure from Table 1.) Next divide the actual gallons per kwh. by the theoretical gallons per kwh. to secure the wire to water efficiency.

To illustrate:

Assume a monthly pumpage of 32,640,000 gallons and a monthly power consumption of 30,200 kwh. Say the total head noted was 220 ft. Dividing 32,640,000 by 30,200 gives an actual pumpage of 1,081 gallons per kwh. Dividing 318,200 by 220 ft. gives a theoretical value of a possible 1,447 gallons per kwh at 100 per cent efficiency (see table). Then:

$$\frac{1{,}081 \text{ (observed)}}{1447 \text{ (theoretical)}} = 74.7\% \text{ overall}$$

wire to water efficiency.

A more accurate method of making the tests is to measure the power input for an hour, or some other convenient period of time. During this period carefully check the output of the pump with any suitable main line meter. Keep a close record also of the discharge pressure and of the suction. The integrations on most electric meters in pumping stations cannot be read closely enough for short tests. However, the power company will funish the number of watts consumed for each revolution of the disk, and by counting its revolutions for ten or twenty minutes the rate of power input can be closely ascertained. Or the power company can be asked to measure the power by means of special equipment. Where more than one pump is taking power through the master meter at the same time, the latter method is the only feasible one for testing each unit separately.

Securing Total Head

The total head in feet must first be secured. If the pressure gauge reads in pounds, convert to feet by multiplying the pounds of pressure by 2.31 [feet of water head giving one pound gauge pressure]. The suction will probably be expressed in inches of mercury. Convert this to feet of water head by multiplying by 1.13. Also measure the vertical distance between the center of the pressure gauge and the point of suction measurement. The total head then becomes the sum of the following:

Discharge pressure, in feet	xxx
Suction, in feet	xx
Vertical distance pressure gauge is above point of suction measurement, feet	x
Total Head in feet	xxx

Velocity head has been ignored, as it is a small factor for the relatively high heads which usually exist in water works operation.

If water is delivered to the pump under pressure, then the pump will be working against a head equal to the difference between the discharge pressure and the inlet pressure.

From the data secured during the test, determine the gallons delivered per kilowatt hour. As before, divide this by the theoretical valve for the head against which the pump was operating. This gives the overall wire-to-water efficiency of the installation.

As an example, let us assume an installation where we secured the following test data:

Power input to motor	90.0 K.W.
Rate of discharge	51,840 gal. per hr.
Delivery per KWH	576 gal.
Pressure	146 lb. = 337 ft.
Suction	15 in. = 17 ft.
Difference in gauge elevation	1 ft. = 1 ft.
Total head	355 ft.

Theoretical discharge 335 ft. head (see table) is $\left(\frac{318{,}200}{355}\right) = 897$ gal.

and

Overall efficiency (wire-to-water) is $\left(\frac{576}{897}\right) = 64\%$

If a suction gauge is not available, an approximation may be secured by measuring the vertical distance from the level of water in the clear well to the center of the pressure gauge, adding to this measured distance about two feet for loss in bends, etc.

What the Tests Reveal

Having shown the desirability of frequent tests and having presented a simple method for making them, it may now be interesting to discuss what these tests may be expected to show. In the first place, there have been great increases in the attainable efficiencies of centrifugal pumps within the past few years. Those of modern design may be expected to give up to the following overall (wire to water) efficiencies.

Capacity gpm.	Efficiencies Per cent
200	58
400	63
600	68
800	71
1000	73
1500	75
3000	80
5000	82
Over 5000	85

It will be noted that the larger the pump the higher the efficiencies.

There will be variations from these figures depending upon the head and other conditions. Such are submitted only for the purpose of giving something with which to compare the efficiencies of existing installations. This is important, because it will often be found that older equipment may have retained its original efficiency and yet be so inefficient in comparison with modern equipment, now available, that it is decidedly not economical to keep it in operation. It will be worth while to check the present efficiency of every centrifugal pump now more than ten years old, to determine how great a reduction in power consumption can be secured by replacement with more efficient modern pumps. You may be surprised.

If an old 1,000 gpm. pump, operating at an efficiency of 57 per cent is replaced with a new pump giving an overall efficiency of 73 per cent the same amount of water may be pumped with 22 per cent less power. This means that both the demand rate and the power consumption through each step of the existing rate schedule would be decreased 22 per cent. Such a reduction might prove enough to pay for the new installation in about one year's time. In order to get the gallons per kwh. to be expected at any head, for any efficiency, it is only necessary to determine theoretical gallons per kwh. for that head and then to multiply this theoretical value by the expected efficiency. If the total pumpage in gallons is then divided by this expected pumpage per kwh. the power consumption to be anticipated from the new installation will be secured. Similarly it is possible to determine the anticipated demand rate, which is often as important as is the total kwh. consumption in determining the power bill to be expected from a new installation. Sometimes it is more important.

A Worthy Example

An article by Marshall and Rawlins of Charlotte, N.C., revealed graphically how the power costs were drastically cut at the local pumping station by replacing old equipment with new. These power costs, which had been running about $16.00 per million gallons were cut to about $7.50 per million gallons. This cut was the result of two definite and distinct improvements. In the first place the pumping main was paralleled with a new line. This resulted in reducing the former friction loss materially. This single betterment cut the power cost from $16.00 to $12.00 per million. Following this, the not very old (but less efficient)

pumping units were replaced with modern efficient equipment. This investment, which might appear to the average municipal councilman a questionable expenditure, further reduced the pumping cost to $7.50 per million, representing a very notable day in and day out saving.

Measuring Output of Water

Table 1 has another use. Many plants, especially smaller ones, have no master meters. With the old displacement type pump it was possible to secure the approximate amount of water pumped by installing a pump stroke counter and multiplying the number of strokes by the discharge in gallons per stroke. If the pump were permitted to get into a state of disrepair, this measurement was apt to be in error, but if the pump were kept in good condition it was reasonably accurate. The method about to be outlined for obtaining the output of water from electrically operated centrifugal pumps has possibly a degree of accuracy comparable to the pump counter method.

From the efficiency curve furnished with the pump, determine the pump efficiency for the head under which the pump operates. The curve will show the pump efficiency only. The combined pump and motor efficiency, the so-called wire to water efficiency, will be about 90 per cent of the efficiency shown for the pump alone. From Table 1 secure the theoretical gallons per kilowatt hour for the head under which the pump is operated. Multiply this by the overall wire to water efficiency just secured. This gives the number of gallons per kilowatt hour the pump should deliver. Multiply this by the total number of kilowatt hours used over any given period of time and the result should be the number of gallons pumped over the same period. To illustrate:

Assume a pump with an efficiency of 65 per cent operating at a total head of 200 ft. Then 90 per cent of 65 would give an overall wire to water efficiency of 58.5 per cent. If the installation were 100 per cent efficient, Table 1 indicates the discharge woud be 1,592 gallons per kilowatt hour. With an overall efficiency of 58.5 per cent the discharge would be 1,592 × 58.5 per cent, or 931 gal. If the power consumption for the month be 20,000 kilowatt hours, then the total pumpage becomes 20,000 × 931 or 18,620,000 gal. for the month.

While this method of computing pumpage will not, as a rule, give results as satisfactory as those secured from a master meter, it does give a close approximation in instances where a master meter is not available.

In outlining the tests in this paper it has not been intended to supplant the more detailed methods used by professional engineers, but to make available to the average water works operator a method of checking which will give reasonably accurate results.

HOW TO PACK A STUFFING BOX

1. Remove all old packing from the stuffing box.
2. Clean box thoroughly, removing accumulations from walls.
3. Keep packing clean during application. The scoring of rods, shafts or sleeves often results from grit or foreign matter picked up by packing.
4. Determine size of packing required by checking diameter of rod or shaft and the inside diameter of the stuffing box. Rods wear and the packing has to compensate for this wear.
5. Never wind a length of packing into a stuffing box. Use ring form only.
6. Cut spiral or coil from packing over a shaft or mandrel of exactly the same size as the one on which the packing is to be used in order to get close fitting rings.
7. Obtain sharp clean cuts on soft packings that tend to squash or become ragged by simply applying a small piece of friction tape at the place where the packing is to be cut. It is advisable to remove the tape when installing the rings. String also serves well for tying the packing on each side of where the cut is to be made and may be left on the packing when installed.
8. Cut all packing ring joints to a snug fit making the rings meet with a tight butt or bevel joint.
9. Seat each packing ring carefully before placing the next one in the box. Loading a stuffing box with packing and then pulling up on the gland follower may cause excessive deformation of the first two rings, building up localized gland pressure and failure to seat the bottom rings so they can work effectively.
10. Install all packing rings so that joints are staggered and kept approximately 90 deg. apart. Spot joints in clockwise direction to facilitate locating them when removing packing.
11. Pull up the gland follower sufficiently tight, after the packing has been installed, to insure final seating of the packing. The nuts should be backed off two or three turns to relieve excessive pressure. Adjust packing to operating conditions.
12. Keep the following in mind for stuffing boxes provided with water, oil or grease lanterns: (a) Make sure that the lantern is so located in the box that as the packing is taken up, the lantern will be advanced to its proper location with respect to the opening in the box. (b) Check to see that the opening into the stuffing box is free from obstructions so that the sealing water or lubrication can flow into the lantern.
13. Allow packing to leak a small amount, if possible, when starting a newly packed pump. Take up the gland slowly as the packing seats.
14. Provide means for lubricating the rod and packing wherever possible.
15. Finally, carefully wrap all extra packings, place them back in their container as a precaution against waste and the possibility of their picking up dirt and other injurious foreign substances.

Courtesy of *Power*

HELPFUL HINTS FOR HANDLING PACKINGS

1. Use packings of correct size. Oversize packings are difficult to install and may cause excessive friction. Undersize packings may be ruined by too much takeup.
2. Where leakage cannot be permitted, provide a means of introducing a sealing or lubricating fluid such as water, oil or grease into the stuffing box.
3. When renewing packings, use all new, clean packing. Worn packings are dry, highly compressed, have high friction, may develop scoring.
4. Remember packing is relatively cheap. Labor and materials necessary to replace worn shafts, sleeves or rods are expensive and critical commodities.
5. Take up bolts evenly, moving to the bolt diametrically opposite, never to the bolt adjacent.
6. Follow up bolts the next day after installing new gaskets. For lines carrying high pressures, the gradual building up of the pressure and continuous follow-up of bolts is recommended.
7. Exercise great care when using gasketing dopes. Never use oil or grease on a rubber or rubber-compounded gasket. Graphite and glycerine or molasses compounds are not injurious to rubber. Never use dope on both sides of gasket—it may cause slippage or blowout.
8. Do not use a heavier sheet packing than is necessary. The thinner the gasketing material, the better.
9. Ring gaskets are preferable to full face gaskets where the flanges are heavy enough to prevent distortion.

Courtesy *Johns-Manville Corp.*

Centrifugal Pump Maintenance and Troubleshooting

1. A Maintenance Timetable

"A" TIMETABLE, not "the" timetable! Operating conditions vary so widely that to recommend one schedule of preventive maintenance for all pumps would be absurd.

So consider this timetable as *relative*. The recommended inspection and service operations may seem too frequent, however, they are based on the severest applications. At any rate, a routine maintenance schedule should be set up and followed to really get the best service out of any pumping equipment.

Every Month

Check bearing temperature with thermometer—not by hand. If anti-friction bearings are running hot, probably they have too much lubricant. Relieve. If sleeve bearings are running too hot, probably they need more lubricant. If change in lubrication doesn't correct condition, dissasemble and inspect bearing. Or possibly the alignment of pump and motor should be checked.

Every 3 Months

Drain lubricant, wash out oil wells and bearings with kerosene. In the case of sleeve bearings, check to see that oil rings are free to turn with the shaft. Repair or replace if defective. Refill with lubricant recommended by your pump manufacturer.

Measure bearings for wear, replace if excessive. Generally, allow 2 thousandths of an inch clearance—plus 1 thousandths of an inch for each inch or fraction of an inch of shaft journal diameter.

Every 6 Months

Replace packing—use grade recommended by pump manufacturer. Be sure seal cages are centered in stuffing boxes at the entrance of water seal piping.

Check shaft sleeves for scoring that would accelerate packing wear—order new sleeves if needed.

Check alignment of pump and motor—shim up units as needed. If misalignment recurs frequently, inspect entire piping system. Unbolt piping at suction and discharge nozzles to see if it springs away—indicating strain on casing. Check all piping supports for soundness and effective support of load.

Every Year

Remove rotating element. Inspect thoroughly for wear—order replacement parts where necessary. Check wearing ring clearances. Generally, they should be approximately no more than .003″ per inch on diameter of wearing rings.

Remove any deposit or scaling. Clean out water seal piping.

Measure total suction and discharge lifts as test of pipe conditions. Record figures and compare them with figures of next test.

Inspect foot valves and check valves—especially check valves, which must safeguard against water hammer when pump stops.

2. How to Locate Trouble

No Water Delivered

CAUSES	CURES
1. Lack of prime.	Fill pump and suction pipe *completely* with water.
2. Speed too low.	Check whether motor is directly across-the-line and receiving full voltage. Or frequency may be too low, motor may have an open phase. Correct.
3. Discharge head too high.	Check pipe friction losses. Larger piping may correct condition. Are valves *wide* open?
4. Suction lift too high.	If no obstruction at inlet, check for pipe friction losses. However, *static* lift may be too great. Measure with mercury column or gauge while pump operates. If static lift is too high, water to be pumped must be raised or pump lowered.
5. Impeller completely plugged.	Remove top of pump casing and clean impeller.
6. Wrong direction of rotation.	This sometimes occurs! Compare turning of motor with directional arrow on pump casing.

Parts 1 and 2 are from an Allis Chalmers Mfg. Co. booklet

Not Enough Water Delivered

CAUSES	CURES
7. Air leaks in suction piping.	If liquid pumped is water or other non-explosive—and explosive gas or dust are not present—you can test flanges for leakage with flame or match. For such liquids as gasoline, suction line can be tested by shutting off or plugging inlet—putting line under pressure. Seal leaks.
8. Air leaks in stuffing box.	Check to see if thin stream of water flows from stuffing box while pump operates. If not—and adjusting gland to reasonable extent does not produce flow—new packing probably is needed. Or—water seal piping may be plugged and need cleaning out . . . lantern ring may be displaced and need centering at water seal piping.
9. Speed too low.	See item 2, above.
10. Discharge head too high.	See item 3, above.
11. Suction lift too high.	See item 4, above.
12. Impeller *partially* plugged.	See item 5, above.
13. Defective wearing rings.	Inspect. Replace if worn excessively.
14. Defective impeller.	Inspect. Replace if damaged or blade sections badly eroded.
15. Defective packing.	Replace packing . . . and sleeves, if badly worn.
16. Foot valve too small or partially obstructed.	Inspect. Area through ports of valve should be at least as large as area of suction pipe—preferably 1½ times. If strainer is used, net clear area should be 3 to 4 times area of suction pipe.
17. Suction inlet not immersed deep enough.	If inlet can't be lowered—or if swirling eddies through which air is sucked persist when it is lowered—chain a board to suction pipe. It will be drawn into eddies, smothering the vortex.
18. Wrong direction of rotation.	Symptoms are an overloaded drive and about ⅓ rated capacity from pump. Compare turning of motor with directional arrow on pump casing.

Not Enough Pressure

19. Speed too low.	See item 2, above.
20. Air or gases in liquid—e.g. marsh gas in swamp water. (Test in laboratory, reducing pressure on liquid to pressure in suction line. Watch for bubble formation.)	May be possible to overrate pump to point where it will provide adequate pressure despite condition. Better to provide gas separation chamber on suction line near pump, and periodically exhaust accumulated gas.
21. Mechanical defects.	See items 13, 14, 15, above.
22. Too small impeller diameter (probable cause, if none of (above).	Check with your pump manufacturer to see if a larger impeller can be used. Otherwise, cut pipe losses, or increase speed . . . or both, as needed. *But be careful that you don't seriously overload your drive.*

Pump Works for a While and Quits

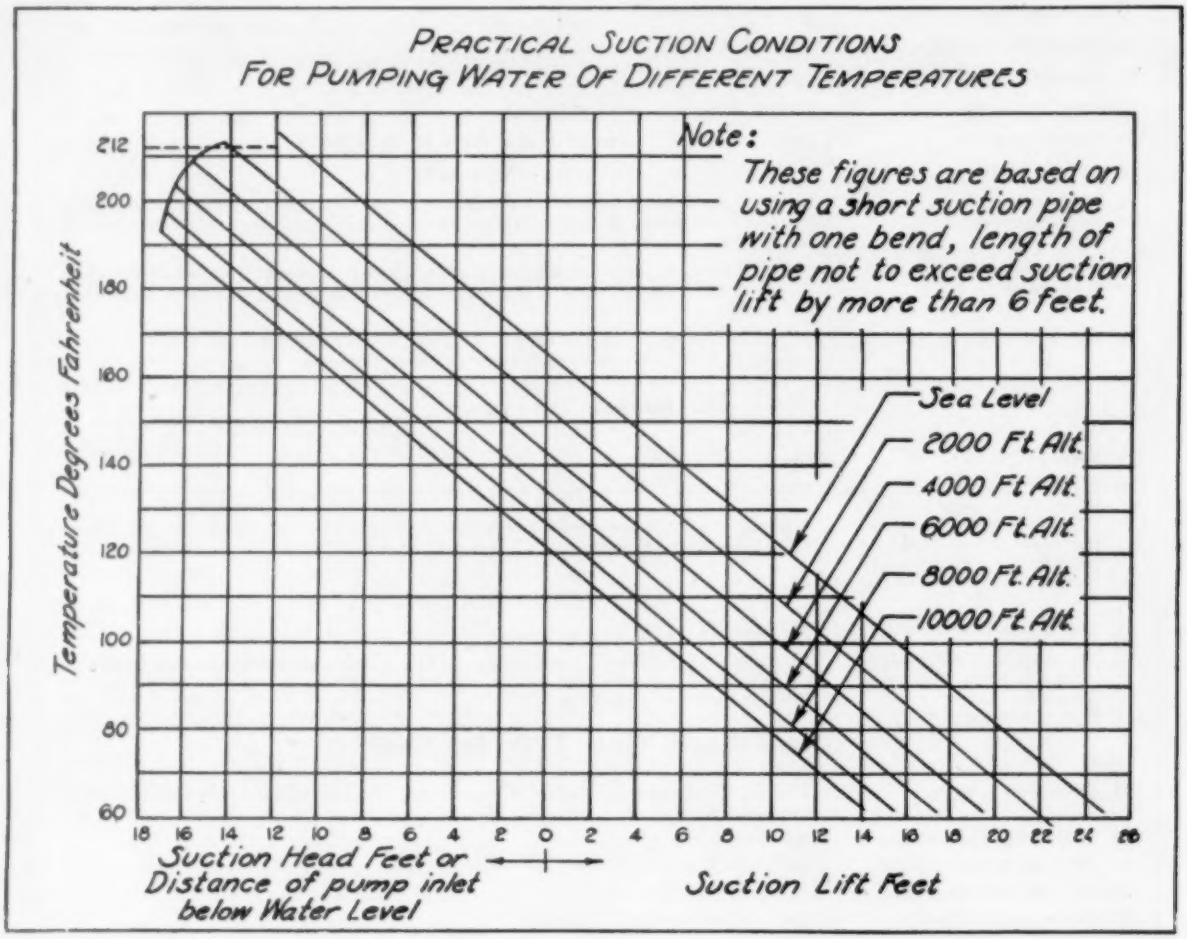
23. Incomplete priming.	Free pump, piping and valves of *all* air. If high points in suction line prevent this, they need correcting.
24. Suction lift too high.	See item 4, above.
25. Air leaks in suction piping.	See item 7, above.
26. Air leaks in stuffing box.	See item 8, above.
27. Air or gases in liquid.	See item 20, above.

Pump Takes too Much Power

28. Head lower than rating, pumps too much water.	Turn down impeller's outside diameter in amount advised by your pump manufacturer.
29. Liquid heavier (in either viscosity or specific gravity) than allowed for.	Use bigger motor.
30. Wrong direction of rotation.	See item 18, above.
31. Stuffing boxes too tight.	Release gland pressure. Tighten reasonably. If sealing water does not flow while pump operates, replace packing. If packing is wearing too quickly, replace scored shaft sleeves and keep water seeping for lubrication.
32. Casing distorted by excessive strains from suction or discharge piping.	Check alignment. Examine pump for friction between impeller and casing, worn wearing rings. Replace damaged parts.
33. Misalignment.	Realign pump and motor.

Pumping Warm Water

For a particular temperature, the actual theoretical height that water can be drawn by suction by a perfect vacuum at sea level is obtained by subtracting the vapor pressure (in feet) of water at that temperature from 38.9 feet. For example, at room temperature (72° F.) this theoretical limit becomes 33 feet, and at 160° F., this limit is 22.9 feet. Since proper allowance must be made for water velocity and friction, the practical limits are less than the theoretical. If the water is hot enough, it is necessary to place the pump below the level of the water so that there is an actual head on the suction. The following chart gives practical suction lifts and suction heads for pumping water of different temperatures and at different elevations.


Practical Suction Conditions
For Pumping Water Of Different Temperatures
Note:
These figures are based on using a short suction pipe with one bend, length of pipe not to exceed suction lift by more than 6 feet.
Sea Level
2000 Ft. Alt.
4000 Ft. Alt.
6000 Ft. Alt.
8000 Ft. Alt.
10000 Ft. Alt.
Temperature Degrees Fahrenheit
212
200
180
160
140
120
100
80
60
18 16 14 12 10 8 6 4 2 0 2 4 6 8 10 12 14 16 18 20 22 24 26
Suction Head Feet or Distance of pump inlet below Water Level
Suction Lift Feet

Horse-Power and Electrical Data

(a) 1 H.P. = 0.746 KW. = 746 watts.

(b) Brake H.P. $= \frac{\text{KW. input}}{0.746} \times$ motor efficiency.

(c) Water H.P. $= \frac{\text{g.p.m.} \times \text{head in ft.}}{3960}$

(d) H.P. to lift water $= \frac{\text{g.p.m.} \times \text{head in ft.}}{3960 \times \text{pump efficiency.}}$

ELECTRICAL EQUIPMENT OPERATIONS*

ELECTRIC power is reliable, readily available, simple to obtain and relatively low in cost. It offers an excellent source of power for operating pumps, instruments, controls, chemical feeders and lighting and communication systems.

Definitions

To understand electricity and electrical equipment it is necessary to be acquainted with a few fundamental definitions.

Alternating current (A.C.) is electricity which flows from the generator in one direction for a definite period of time and then reverses and flows in the other direction for the same period of time.

Cycle or frequency is the number of times alternating current reverses its direction each second. Most common is 60 cycle, although some older systems are 25 cycle.

Direct current (D.C.) flows in but one direction. Battery output is direct current. D.C. can also be generated but is not used much.

Units of electrical measurement include: *Volt* (V), electrical pressure or potential; *ampere* (Amp.), rate of flow; *ohm* (R), resistance; *watt* (W) or *Kilowatt* (KW), electrical power. Electricity is usually sold on the basis of kilowatt-hours (KWH) or number of KW of power consumed times the number of hours involved.

Phase refers to the time relation between current and potential. In single phase, there is one applied voltage. Two phase circuits have two applied voltages, 90 degrees apart (one maximum when the other is minimum). Three phase circuits have three applied voltages, 120 degrees apart.

Power Factor of a circuit is the ratio of the true power passing through it to the product of the volts times the amperes.

Load Factor is the daily (monthly, yearly) ratio of the average power to the maximum power used by a machine, plant or system.

Demand Factor is the ratio of the maximum load actually taken by an installation, to the total connected load (sum of ratings of all apparatus).

Equipment

In the design of water and sewage works, provisions must be made for receiving, conveying and using electrical power. Equipment includes transformers, switchboards, circuit breakers, motor, circuit and meters.

Type of equipment must conform to the type of electrical current available. Most power lines in this country carry three-phase, 60 cycle alternating current, but in some instances direct current is available.

Voltages used depend on type of equipment: 110 volts for lighting, small motors, and appliances. Larger motors use 220, 440, 550, 2200, or 4000 volts, depending on size; the latter two voltages are used for motors of 60-100 hp and more.

Types of Motors

In selecting electric motors, considerations should be given to: Suitability; speed, speed regulation, control, starting ease, current, and torque; power factor, rated power, partial load characteristics; and type of enclosure.

Types of motors include: Induction motors (both wound rotor and squirrel cage), and synchronous motors. The former may be obtained in single-phase and polyphase, with single phase being heavier, more costly, less efficient, more difficult to start but with a lower power factor. Squirrel cage induction motors are frequently considered as most suitable for driving water works pumps. Synchronous motors have better power factors, and higher efficiency but cost more originally than squirrel cage motors, and require a source of D.C. power for the exciter. They are usually used in sizes, 200 hp and over.

The design of motors depends on use and installation in many instances. There are open motors, partially enclosed, totally enclosed; drip proof, splash proof, water-proof, submersible, gear, brake, etc. Submersible motors are used with deep well and sump pumps. Motors may be direct connected, close coupled, or magnetic drive for connection to pumps, or may drive equipment from jack shaft or through gears.

Motor speed is an important factor in the selection of electrical motors. High speed motors cost less but slow speed motors are used for equipment that moves slowly like flocculators and clarifier rakes. Frequently the speed is reduced through a gear train. Variable speed motors find application with centrifugal pumps if the demand for water is not constant.

Installation

The setting of motors is important to the proper operation of both pumps and motors. The foundation must be large and stable enough to prevent vibration and must be level to prevent misalignment of pump and motor.

Transformers are used to step down the transmission line voltage to that of the equipment. As a matter of safety, transformers should be placed in fireproof rooms or at points protected from personnel traffic in water or sewage works.

Relays and circuit breakers are used to protect equipment, and to start and stop motors, pumps.

Switchboards contain the necessary devices to start and stop motors; close and open valves; operate relays; and house meters, recording and indicating instruments, etc.

In the installation of all electrical equipment safe practices must be followed. The National Electric Code Handbook contains details of standard practice; standard ratings of electrical equipment have been set by the Am. Inst. of Elect. Engrs.; and standards for electrical equipment and installation methods have been adopted by the Nat. Bd. of Fire Underwriters and the Amer. Stds. Assn.

Operation Problems

In addition to standard safety precautions with regard to personnel, there are a number of precautions to be taken to protect the equipment itself. Motors must be protected against too much or too little voltage; too much or too little load; reverse current, reverse power; reverse phase, lightning, current surges. Fuses or circuit breakers are used for overloads.

Motors should not be operated above an ambient temperature of 40°C, unless especially designed for high temperatures. Moisture and dust must be kept out of motors.

Motors may be started "across the line" or at "reduced voltage" depending on the capacity of the supply system. Motors operating centrifugal pumps are started with the discharge valve closed to reduce starting load.

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*Material for this discussion is based in part on Chap. XIV on "Electrical Equipment" in *Water Supply Engineering* by Babbitt & Doland (McGraw-Hill).

FLOW MEASUREMENT

FLOW IS quantity in movement past a point in a specified interval of time. Velocity is rate of linear movement in an interval of time. Velocity or some function of it is a fundamental factor in flow measurement; all common measuring devices are based on this concept.

Rate of flow is the measurement of quantity in motion for a relatively short period of time.

Total flow is the total amount of liquid moved during a period of time; usually a day, month, year. Total flow equals average rate of flow multiplied by time.

Units of flow commonly used in water and sewage practice are cu ft per sec (cfs); gal per min (gpm) and mil gal per day (mgd).

Reasons for Flow Measurement

Rates of plant output as well as pressure in lines are important. Total plant production in a day, week, month or year help chart trends for future planning. Rates of operation and output of individual operating units aid in proper operation and maintenance of filters, pumps, wells, wash water service, chemical feeders, electrical equipment.

Determination on efficiency of plant and unit operations and control of unit operations are also functions of flow measurement. Flow measurements are made to ascertain quantity of water sold and amount of non-revenue water; to determine the costs of operation, and to provide records of permanence.

In a sewage works the reasons for flow measurement are made to provide data and information on plant operation; to determine plant operating efficiency; to control unit operations, sewage and sludge flow, digester operation, sludge disposal, chemical feeding, etc. to determine operating costs; and to provide permanent records of performance.

Metering Points

In water works points of flow measurement include:

Source of supply—Letdown from reservoirs, raw surface water intake, raw water pump discharge, wells and well field output.

Treatment—Flow to or from coagulating basins and settling or softening basins; wash water to supply tank; wash water to filters; effluents from filters, finished water to clear wells.

Distribution—Transmission mains; high service pump discharge, elevated tank storage; booster pump discharge; interconnections to other supplies; consumers services.

Plant Water Supply (inside and outside), oil, gas and electricity.

In sewage works points of flow measurement includes:

Sewers—Main sewers, Interceptors, Tributary, lift stations, sampling stations.

Primary Treatment—Plant influent, bypass, sludge.

Disinfection—Chlorine, water for chlorination.

Secondary Treatment—Trickling filter influent, dosing tanks, sludge from clarifiers, recirculation.—Activated sludge influent, return sludge, waste sludge from clarifier, air volume, ratio of air to sewage and return sludge to sewage.

Sludge Digestion—Raw sludge, digested sludge, supernatant liquor, gas, heating water, recirculation.

Sludge Disposal—Volume handled, sludge dewatering, elutriation, chemicals, etc.

Plant water, portable water, oil, gas, electricity.

Devices for Flow Measurement

Head-area meters are used only for open channel flow or flow in partly filled pipes. They operate on the principle that a constriction or barrier in the flow channel will back up the liquid creating a high level (or head) than the level below the barrier; this head is a function of velocity and therefore rate of flow. Head-area meters include weirs, measuring flumes (Parshall flume) and open-end nozzles.

Functional meters are mechanical devices which measure some function of volume in movement and by means of other mechanical devices convert that measurement into rate of flow or total flow.

Functional meters include: (1) Differential head devices (Venturi tube, insert nozzle, orifice, Dall flow tube, Gentile flow tube); (2) Velocity meters; and (3) Pitot Tubes.

Pumps are not generally used but reciprocating pumps of controlled output may be used; centrifugal pumps are not good metering devices.

Displacement meters operate on the basis of the fill and draw principle. Meters for household services are usually of this type.

Miscellaneous devices for flow measurement include: the constant differential meter or rotameter; and inertial flow meters.

Selection of Primary Units

The devices which measure the flow are called primary units; devices which indicate, totalize or record flows are called secondary instruments.

Considerations which affect the selection of primary units include: Type of service, engineering factors, installation factors, accessories, comparative characteristics, and operators convenience.

Engineering factors include allowable permanent head loss, size of constriction, differential head, distance to secondary unit, type of transmitter; types of ends, corrosion resistance, etc.

Comparative considerations include: Accuracy, cost, capacity, range, permanent head loss, life expectancy, freedom from field tapping, freedom from upstream disturbances, ability to handle liquids containing solids, ability to handle pressure, laying length, and ease of installation.

Operating Problems

Foreign bodies such as bricks, rocks, concrete, lumber, grease, jute, etc. have been found in primary devices. Any foreign matter in a primary unit will adversely affect the accurate operation of flow measuring devices. The remedy is to remove the material.

Negative head exists in metering instruments under certain conditions of installation and adversely affects the proper reading of the secondary instrument.

A knowledge of the construction, operation and adjustment of equipment, plus proper tools, spare parts, and a preventive maintenance schedule are essential factors in insuring against costly breakdowns. A sound maintenance schedule will include arrangements for a regular visit of a factory trained service man.

METERS : GAGES : CONTROLLERS
for Sewage Treatment and Water Supply

BAILEY METER COMPANY

WATER & WASTE TREATMENT DIVISION

1072 IVANHOE RD., CLEVELAND, OHIO

Bailey Meter Company Limited, Montreal, Canada

Atlanta	Charlotte	Cleveland	Detroit	Los Angeles	New Orleans	Pittsburgh	Seattle
Boston	Chicago	Dallas	Houston	Memphis	New York	San Francisco	St. Louis
Buffalo	Cincinnati	Denver	Kansas City	Milwaukee	Philadelphia	Schenectady	St. Paul

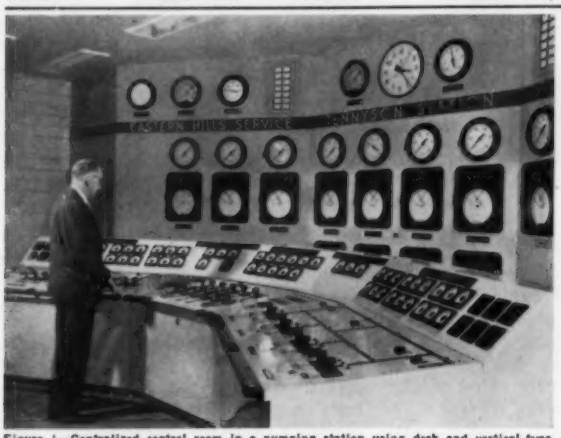


Figure 1—Centralized control room in a pumping station using desk and vertical-type panels.

CENTRALIZED CONTROL

The use of centralized control rooms in water supply and sewage treatment plants helps designers to secure fully co-ordinated operation and greatly reduced man-power requirements. When planning centralized control installations you now have available a line of Bailey products developed especially for this service. These products which are described in Bulletin 17 include:

1. Bailey Pneumatic and Electric Transmitters.
2. Bailey Receiver-Recorders and Indicators.
3. Bailey Pneumatic Control Components.
4. Bailey ARMORTUBE Cable for carrying Pneumatic Signals.

TELEMETERING SYSTEMS

Figure 2—Bailey Receiver-Recorder for pneumatic and/or electric signals.

Pneumatic and/or electric signals actuate Bailey Telemetering Systems. Either or both may be received in the Type WM55 Receiver-Recorder (Product Specification E12-5). Multiple receivers may be connected to one transmitter. Several flow measurements can be totalized on one record. Automatic control may also be part of the measuring and telemetering system.

For a complete list of factors such as flow, level, pressure, temperature, pH, conductivity, turbidity and speed which can be measured and telemetered, ask for Bulletin 17.

CHEMICAL FEEDERS

Electric or pneumatic signals from Bailey Registers may actuate chemical feeders, fluid sampling devices, alarms, or pump controls.

BAILEY REGISTERS

Figure 3—Mechanically operated register.

Bailey Registers measure flow of sewage, industrial waste, sludge, dirty water or other liquids in open channels or in pipelines. They also measure air flow, pH, liquid level in open and closed tanks and reservoirs and other factors.

Pneumatic and/or electric signals established by Bailey Registers may actuate automatic control systems.

Figure 4—Bailey Filter Operating Panels of the indicating type.

Figure 5—Bailey Filter Operating Panels of the recording type.

The following are typical applications:

. . . FOR OPEN CHANNELS

The Bailey Flume or Weir Meter is simple and accurate. It consists of a single float connected by a flexible cable to a sturdy indicating, recording and integrating mechanism, which may be mounted on a panel board, a wall or a column. Remote location may be obtained by the use of a Bailey Telemetering System. Ask for Bulletin M22-5.

. . . FOR PIPELINES

The Bailey Fluid Meter accurately measures flow of steam, liquids, and gases in pipelines at high or low pressures. A venturi tube, flow nozzle or orifice is used as the differential producing device and the meter indicates, records and integrates on a standard Bailey Register. This meter may also provide records of pressure, temperature or liquid level on the same chart. Ask for Bulletin 301.

. . . FOR LIQUID LEVEL

Bailey Registers may be used in measuring liquid level in open tanks and reservoirs. Three methods are available:

Open Float Method—For location above liquid level.

Static Pressure Method—For location below liquid level.

Bubbler System—For measuring level or specific gravity of corrosive liquids and for liquids with solids in suspension. For more information on Bailey Level Recorders ask for Bulletin 17.

. . . FOR AIR FLOW

Bailey Air Meters measure air flow in main lines and in individual lines to aeration tanks. The register used is similar in appearance to the standard Bailey Fluid Meter and is designed to operate on a maximum differential pressure of 8″ of water.

Air flow from a rotary positive type blower can be measured accurately with a Bailey Electronic Type Recorder measuring blower shaft speed by means of an electric tachometer. This may be calibrated to record in terms of air flow.

. . . FOR RATE CONTROL

The Bailey Rate Control System is designed to meet the specific requirements of each application. It operates at peak efficiency on either filter backwash, filter effluent, or filter surface sand wash system. Meter differentials available from 12.5 to 1200 in. of water.

ARMORTUBE CABLE

Figure 6—Bailey ARMORTUBE Cable.

This protected multitube cable for pneumatic transmission lines minimizes installation costs and provides inherent hazard-proof protection for control systems. It is stocked in three sizes of 4, 8 and 12—¼″ O.D. copper or aluminum tubes encased in heavy rust-resistant galvanized steel strip. Ask for Bulletin G91-9.

Main Line Metering With Propeller Meters

by JAMES M. MONTGOMERY
Consulting Engineer, Pasadena, Calif.

THE principle of the current meter has been used as a primary metering element for the measurement of stream flows for many years. Since 1924 this same current meter principle has been applied as a primary element for the measurement of main line flows by the Sparling Meter Co., Los Angeles, California, and since 1944 by Builders-Providence, Inc., of Providence, R.I. This type of meter has proven itself well suited for this purpose.

Characteristics

The current metering principle is well adapted for main line measurement as the action of the propeller is solely dependent upon the velocity of the flow in the line. The pressure requirement is only that which will always maintain a full pipe of water. The loss of pressure caused by the metering element in sizes 6-in. and larger does not exceed 6 inches of water at normal maximum pipe velocity.

Continued accuracy of the current type meter is dependent chiefly upon maintaining a clean metering section, keeping the propeller free from incrustation and preventing solids, which might damage the propeller, from entering the pipe line. The plastic propeller has proven itself well suited for this purpose, as it is practically inert and will resist both corrosion and electrolytic action. In order to maintain a uniform meter section the propeller assembly may be mounted either in a cast iron, steel, or bronze tube with a liner and straightening vanes.

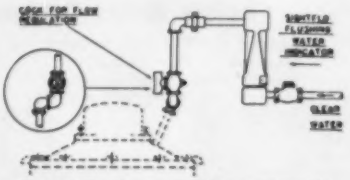


Fig. 1—Continuous flushing system with Builders Sightflo indicator

Meter Features

Propeller type meters as manufactured by the Sparling Meter Co., and by Builders-Providence, Inc., have high accuracy over wide range, measuring within plus or minus 2 per cent of actual flow from about 10 per cent to 100 per cent rated capacity. Both manufacturers' meters have an "open upper limit" or temporary overload range, where the meters will continue to register with good accuracy at rates up to at least 150 per cent of rated capacity. Both the Sparling and the Builders meters are self-contained and self-operated, requiring no mercury, pressure piping or electrical connections; they are as easy to install as a valve or fitting with no adjustments required in the field.

One feature of the Builders Propeloflo Meter is the Venturi design. This produces an increased and consequently more stable velocity at the point where the fluid acts on the propeller. This increased velocity also produces added power, which is of value when applying secondary units to the meter.

Both types of meters can be used with secondary instruments, either cable-driven or electrically-operated totalizers only, totalizer-recorders or totalizer-indicator-recorders for nearby or remote location, when so specified. They may also be used in conjunction with electric alarm registers, where measurement of a pre-determined quantity of liquid is required.

With the Builders, Propeloflo Meter a continuous flushing system is recommended when metering the flow of liquids containing gritty materials or heavy concentration of solids. This system introduces a small continuous back flow of clear water into the propeller hub, thus preventing the solids-bearing liquid from reaching the propeller shaft bearing. The Builders Sightflo Indicator in this system gives a visual indication that the back flow is adequate and is properly maintained. (See Fig. 1)

The Propeller

The propeller type meter, as illustrated in Figs. 2 and 3, is made up of a 6-blade propeller, approximately 8/10 of the internal pipe diameter mounted transversely in the center of the pipe. The propeller is made of plastic material, having a specific gravity of approximately 1, and is suitable for use in either cold water or hot water, up to 250° F. For special liquids the plastic propeller may be replaced by an aluminum propeller, or stainless steel propeller,

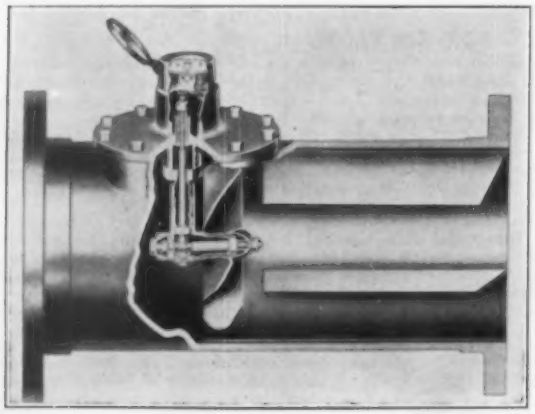


Fig. 2—Cutaway view of Sparling propeller meter
(Note the flow-straightening vanes)

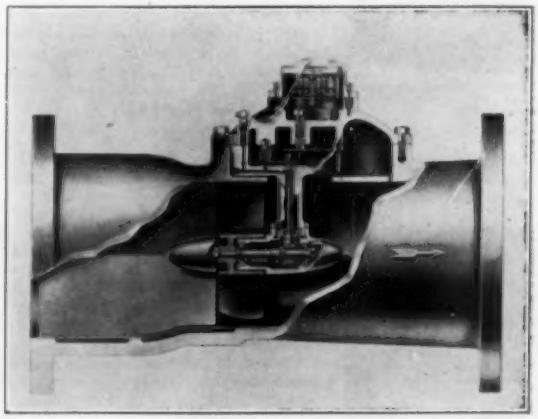


Fig. 3—Cutaway view of Builders Propeloflo meter
(Note the Venturi design and streamlined nose of propeller mechanism)

depending upon requirements. The propeller, when made of plastic, practically displaces its own weight in water and is mounted on ball bearings, which allow it to rotate freely in the stream of water.

Installation

The metering element may be installed directly on an existing pipe line by means of a saddle either bolted or welded directly on the main. In such installations it is important that the inside diameter of the pipe be accurately determined and the meter properly centered. In all installations the meterhead may be removed from the pipe line very quickly and easily and it is normally good practice to make a yearly inspection.

In selecting the proper location for the metering element it should be kept in mind that a normal flow of water, free from either spiraling or jet action, is required for accurate results. The spiraling effect which may be caused in the flow of water passing through a series of elbows, can be largely corrected by installing straightening vanes in the line preceding the meter.

Various forms of such vanes are in use, but a very simple and effective correction may be made by the installation of 3 vanes, each approximately ⅓ the pipe diameter, and 2½ pipe diameters long, set at 120 degrees to each other in the pipe. These vanes will not eliminate a disturbance caused by a partially opened gate valve, but are effective for double elbows or other standard fittings, and with such vanes the manufacturers state that the meter element may be installed with but five pipe diameters of straight approach. However, when possible, a longer section of straight approach is desirable.

A straight run of one pipe diameter downstream from the meter is normally sufficient for all installations. It is always good practice to use the straightening vanes. When the metering element is installed complete with either a flange or bell and spigot tube, straightening vanes are mounted directly inside this metering section to constitute a complete unit, ready for installation.

The metering element may be installed in either a vertical or horizontal pipe and it may be mounted on either the suction or discharge side of a centrifugal pump. In all cases it is required that the line run full.

Standard Specifications

The American Water Works Association has published standard specifications for cold water meters—current type, propeller-driven—known as No. 7M5-T. These cover general description, capacity, size, design, connections, operating mechanism, and notes of special importance.

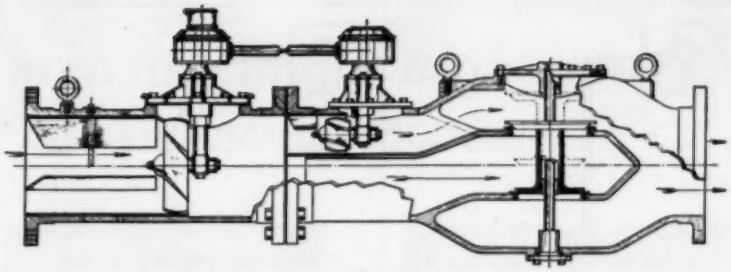


Fig. 4—Section through propeller-type compound meter
(Note valve which closes on low flows to cause entire flow to pass through small meter.)

Calibration

Experiments and experience have shown that a propeller will rotate in direct proportion to the velocity of water in a pipe at all flows above an approximate pipe velocity of ½ linear foot per second. The index, or number of cubic feet passing through the pipe for each turn of the meter shaft, is determined from volumetric tests. From this index proper gears are furnished for direct totalization of the flow.

Compound Design

Fig. 4 is a sectional illustration of a compound meter suitable for use where an extremely wide range of flow measurement is required. This is offered by the Sparling Meter Co., of Los Angeles, and has a range of 150:1. A compound unit consists chiefly of two propeller type meters working in series through a pair of ratchet clutches, allowing the meter revolving at the highest speed to drive the totalizer-register. On a very low flow the large meter will under-register, and thus allow the small meter to drive the totalizer. As the flow increases a pipe velocity is reached where the large meter has come in step and the small meter is operating at a high capacity. At this point the pressure loss caused by the small meter operating on the differential area of the compounding valve forces the valve to lift itself and allow the higher flow to by-pass the small meter.

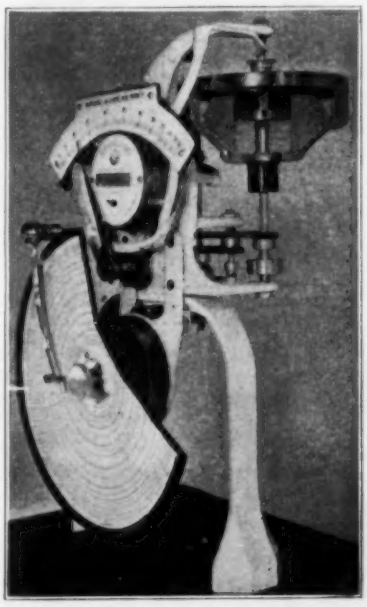


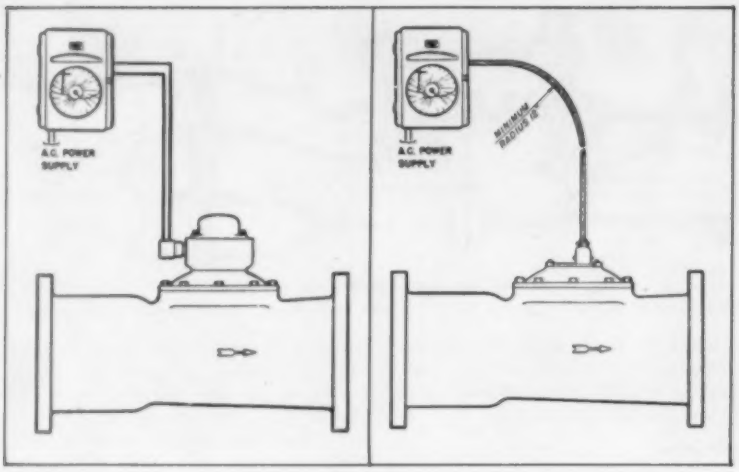
Fig. 5—Typical Sparling indicator-recorder of the mercury governor type

Although the minimum flow is considerably above that of the standard domestic *compound* meter, it is well adapted for main line measurement as the pressure loss caused by the entire unit does not normally exceed 2 pounds at maximum flow.

Indicating and Recording Elements

A rate-of-flow indicating and recording instrument may be used in conjunction with the straight totalizing primary element. The primary step of a current type meter is direct totalization. If the rate-of-flow indication is desired it must be obtained through a secondary step normally involving either a governor bowl or a friction plate revolving at a constant speed with a follower locating itself on the plate by impulses from the primary element.

Figure 5 illustrates the recording instrument involving a governor bowl which is driven either mechanically up to 15 feet from the metering element, or electrically to any distance required. The governor bowl consists chiefly of a float riding in the center of a mercury well. As the governor revolves, the mercury, through centrifugal force, finds its way through a small needle-valve to the outer chamber of the bowl, allowing the float in the center to have a rising and falling action in proportion to the revolving speed of the bowl. This type of governor is effective over approximately a 6-to-1 range and is extreme-



TOTALIZER-INDICATOR-RECORDER
(Electrically-Operated)

TOTALIZER-INDICATOR-RECORDER
(Flexible Shaft Electrically-Operated)

Fig. 6—Diagrams of arrangement for remote totalizer-indicator-recorder (Left—electrically operated; Right—cable electric operated)

ly simple and well suited for normal flow measurement.

A recording instrument utilizing the revolving friction plate, with a follower locating itself by impulses from the metering element, as mentioned above, produces a straight line of rate indication over approximately 25-to-1 range and is well suited for recording flows of main distribution or consumption lines.

Recorders can be adapted to show the combined flows of two or more pipe lines and combinations may be furnished showing the net total of several lines where the flow of any one pipe may be in either forward or reverse direction.

Electrically operated totalizer-indicator-recorders make possible the transmission of liquid flow metering information over any distance (See Fig. 6). A simple two-wire circuit carries the impulse from a transmitter at the Builders Propeloflo meter to the remotely located receiving instrument. Similar remote operation is available for the Sparling meter.

Flexible cable operated totalizer-indicator-recorders (See Fig. 6) permit transmission of liquid flow metering information to any point within a 25-ft. radius of the propeller type meter. In the case of the Builders Propeloflo meter, the flexible cable is connected to the meter either by a straight-type adapter plate or by a right angle take-off. At the receiving instrument, the connection is made through a coupling unit which can be positioned for straight line approach of the cable to the instrument.

Application With Chemical Feeders

Automatic pacing of chemical feeders, by either mechanical or electrical means, is readily obtainable from a current meter element as the shaft of the meter is revolving in direct proportion to the flow and considerable load may be applied without affecting the rotating speed of the propeller.

If given the periodic inspection required by any primary metering element, the characteristic of low pressure loss and accuracy over a wide range of flow allows the principle of the current meter to fill an important part in the water works field.

The propeller-type meter is not suitable for measuring raw sewage and is not generally recommended for measurement of a sewage effluent unless the effluent has passed through a filter bed. When installing such meters on raw water gravity lines, care must also be taken to provide screens at the inlet structure to prevent excessive algae or weeds from passing down the pipe and fouling the meter propeller.

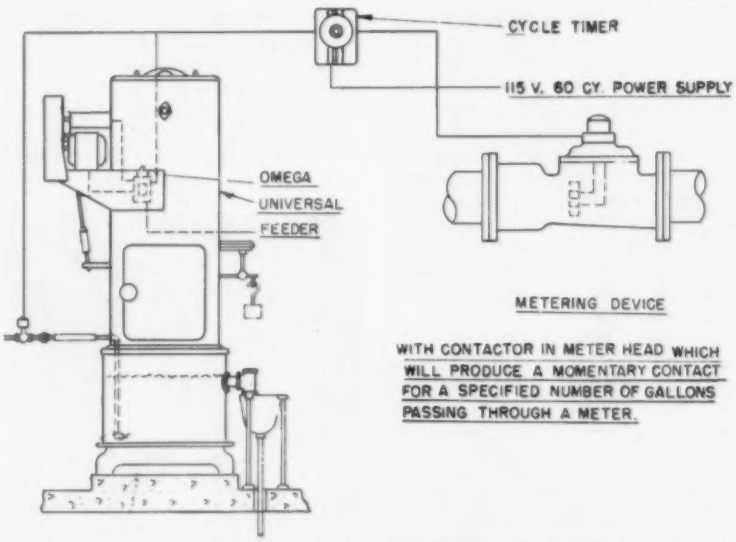
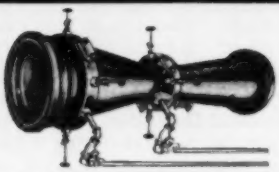

CYCLE TIMER
115 V. 60 CY. POWER SUPPLY
OMEGA
UNIVERSAL
FEEDER
METERING DEVICE
WITH CONTACTOR IN METER HEAD WHICH WILL PRODUCE A MOMENTARY CONTACT FOR A SPECIFIED NUMBER OF GALLONS PASSING THROUGH A METER.

Fig. 7—Propeloflo meter used to pace proportional chemical feeding

For accurate measurement and control

SPECIFY THIS RELIABLE SIMPLEX EQUIPMENT

VENTURI TUBES



Accurately measure sewage, sludge, trade wastes under a wide range of pressures. Flanged, bell or spigot ends in any size or design . . . any metal.

Cleaning valves at main and throat keep piezometer openings clear.

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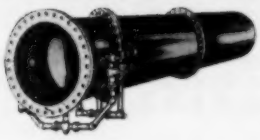
ELLIPTICAL VENTURI TUBES



Developed specifically for *accurate* measurement of low velocity sewage, sludge or heavily laden trade wastes—flowing under low pressures.

Flat top prevents air binding! Flat invert is self-scouring!

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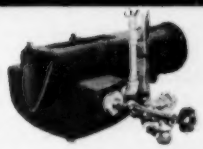
PARABOLIC FLUMES



Measure sewage, sludge and trade wastes under low heads or open flow. Can be used for indicating, or with meter to record and totalize. Simple to install. Full 20 to 1 flow range. Flanged, bell or spigot inlet in 6" to 36" standard pipe sizes.

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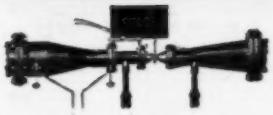
SLUDGE CONTROLLERS



Accurately control flow of sewage, sludge, trade wastes. Most accurate primary device, a Simplex Venturi Tube, has a special throat section of flexible rubber—measures as it controls! Motor-driven clamp adjusts throat . . . keeps flow at control point. Viscous flows contact no moving parts.

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TYPE MO METERS

Most accurate inferential type instrument for water, sewage, sludge, industrial liquors. Indicates, records, totalizes.

Measures within ±2% over ranges up to 20 to 1. Easy-to-read chart. Wall, floor stand, or panel mounting.

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Mercury-float type indicating, recording and totalizing unit. Gives ±2% accuracy at any point for flow ranges up to 13 to 1. Evenly spaced scales make accurate readings easy. Wall, panel, or floor stand mounting.

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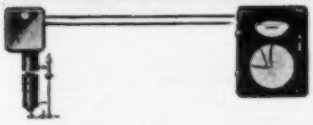
ORTHOFLOW® TRANSMITTER



Electric—New Simplex Orthoflow transmits data over in-plant circuits and leased telephone channels. Accuracy of ±2% for wide ranges.

Receiver—Reliable Type H Meter.

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Pneumatic—New Simplex Laminair is fast and accurate. Permits centralizing instruments in main control panel away from primary devices.

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The 2" size is adaptable for installation on all pressure lines, pump casings.

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LARGE DIAL GAUGES
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Recovery Characteristics of Differential Producers*

IN THE measurement of water or sewage flow, the choice of a metering device may depend on the recovery characteristics of the device, particularly if it is a differential producer.

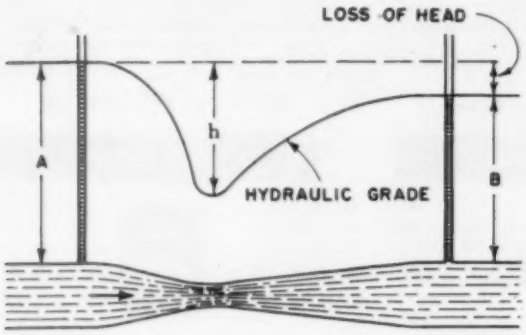


Fig. 1. LOSS of Head

When fluid passes through a differential producer, the line pressure downstream from the differential producer is less than at the inlet (See "A" and "B" in Fig. 1). This difference in pressure is called *loss of head* and is an important consideration in many installations. A high loss may result in inadequate line pressure at some distant point, or in high pumping cost, or in additional expense to elevate water for a gravity distribution system.

RECOVERY CHARACTERISTICS

Fig. 2 shows a comparison of head loss for differential producers commonly used for insertion in a pipe line. This graph is unique in that head loss is plotted against a capacity constant, β^2K, thereby permitting a comparison of primary devices of same inlet size but differing throat sizes which meter identical flows at identical differential pressures. The term β expresses the ratio of throat diameter to inlet diameter while the term K is a combined factor which includes the effects of jet contraction, velocity of approach, velocity distribution and friction. Values in Fig. 2 were obtained by measuring the difference in head between two piezometers, one located one diameter upstream from the differential producer, the other located five diameters downstream, and subtracting the ordinary friction losses in six diameters of pipe. Fig. 2 shows that the Dall Flow Tube and the Venturi Tube have much lower head loss than the orifice plate or conventional flow nozzle (Type A) when metering a given flow at a given differential.

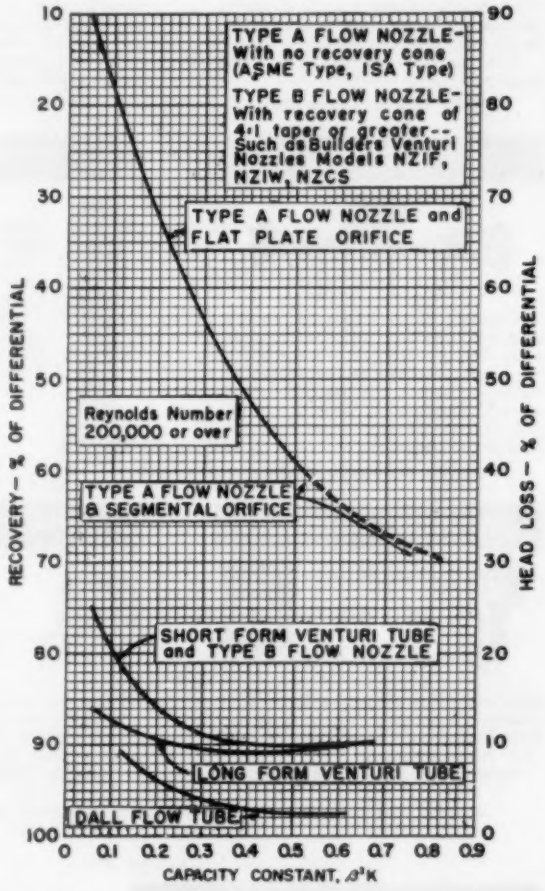


Fig. 2. RECOVERY Characteristics of Differential Producers at Equivalent Capacity

TYPICAL CALCULATIONS

To compute the loss of head, it is necessary to determine β^2K, which can be obtained from the following formula:

*Reprinted from Keep Sheet No. 3A of B-I-F Industries, Inc.

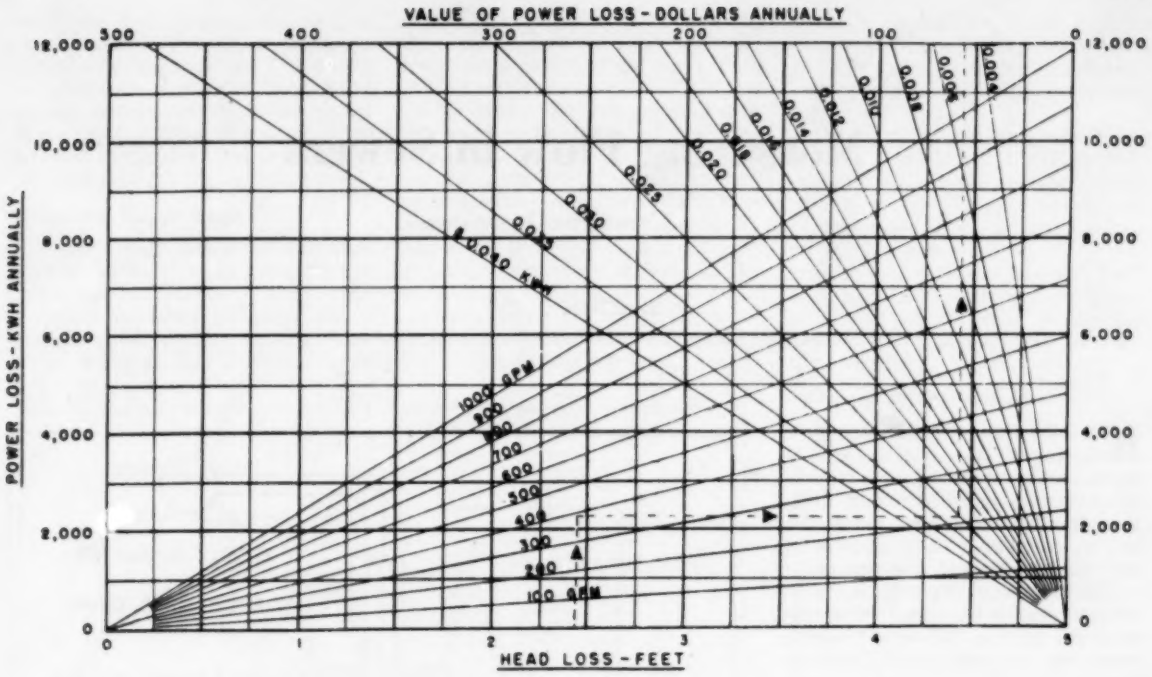


Fig. 3. GRAPH of Annual Power Cost for Various Head Losses

$$\beta^2K = \frac{Q \times 0.1764}{d^2 \times \sqrt{h}}$$

where:
β^2K = Capacity Constant Factor
Q = rated meter capacity, gal/min (water at 60°F)
d = diameter of pipe line in inches
h = differential in inches of water at rated capacity

Knowing β^2K, the head loss, expressed as per cent of differential, can be determined from Fig. 2 for any desired differential producer. To compute head loss at any selected rate of flow, multiply the differential at that rate of flow by the percentage which applies. A complete example is worked out on the next page.

Figure 3 provides a quick means for computing the value, in dollars per year, of power consumed due to head loss, or conversely, the saving due to head recovered, assuming 70 per cent overall pumping efficiency. Starting with a known head loss, read vertically to the proper rate of flow, then horizontally (to the right) to applicable cost per KWH, and then vertically upward to the annual value, in dollars, of power lost or saved.

If the pumping rate is higher than 1000 gpm (the maximum rate on the graph), divide the pumping rate by 10 or 1000 and proceed as directed, multiplying the answer by the same factor.

For example, assume that a differential producer designed for maximum differential of 80 in. is to be installed in a 12 in. line where maximum flow will be 3900 gpm.

From the discussion on the front of this sheet:

$$\beta^2K = \frac{3900 \times 0.1764}{12^2 \times \sqrt{80}} = \frac{3900 \times 0.1764}{144 \times 8.944} = .534$$

From Fig. 2, with $\beta^2K = .534$, the head loss with a Dall Flow Tube is 2.5 per cent of the differential, or since the differential is 80 in., the head loss is 2 in. of water.

For equivalent capacity, at the same differential, Fig. 2 shows that an orifice plate installation (segmental orifice required for this high capacity) would have a head loss of 39 per cent of differential. The loss with the orifice plate, then, is 39 per cent of 80 in. or 31 in. of water. With a Dall Flow Tube, head loss is less than for the orifice by 29 in. or 2.42 ft of water.

With 24-hour pump operation at 3900 gpm (70 per cent overall efficiency) and power cost of $.025 per KWH, the graph in Fig. 3 shows the annual cost of power which can be saved by selecting a Dall Flow Tube for the primary device rather than an orifice plate amounts to $560 (Use difference in head loss of 2.42 ft and 390 gpm rate on graph and multiply answer by factor of 10).

The suitability of a particular differential producer for a given installation depends not only on pressure recovery but also on numerous other factors. Technical data and information on all factors concerned with the selection of any type of differential producer may be obtained from the manufacturer.

Measuring Flow in Sewers

The Ohmmeter Technique

by JOHN D. EYE

Assist. Prof., San. Eng., Virginia Polytechnic Institute, Blacksburg, Va.

KNOWLEDGE of the quantity of sewage or industrial waste being carried by sewers is essential in planning and designing treatment facilities, in planning sewer extensions, and in evaluating waste loads being introduced into receiving waters.

The flow in sewers is generally estimated by: (1) direct discharge measurements; or (2) depth-velocity techniques. In general, the direct discharge methods are more accurate than the depth-velocity methods but usually are somewhat more limited in application. The ohmmeter technique falls within the classification of a depth-velocity method. In the author's experience, this technique has given excellent results and has proven to be extremely versatile.

Method and Techniques

The ohmmeter technique depends on the establishment of a depth-velocity-discharge relationship for the sewer to be gaged, and on the subsequent computation of the hydraulic elements used in an empirical formula such as Manning's. The elements entering Manning's formula for flow are: (1) the slope of the hydraulic gradient; (2) the hydraulic radius; and (3) the roughness coefficient.

The mean velocity of flow is measured either by a current meter or a pitot tube, and the corresponding depth of low is determined by use of the depth gage described in this article. If the slope of the hydraulic gradient is known or assumed, the roughness coefficient can be computed from the above measurements; if the slope is unknown, a value of the roughness coefficient can be assumed and the slope computed for the flow existing at the instant the measurements were made. Channel conditions may cause a change in computed slope with varying depths of flow, it is necessary to extend measurements and computations over the range of flows normally expected.

After the slope and the roughness

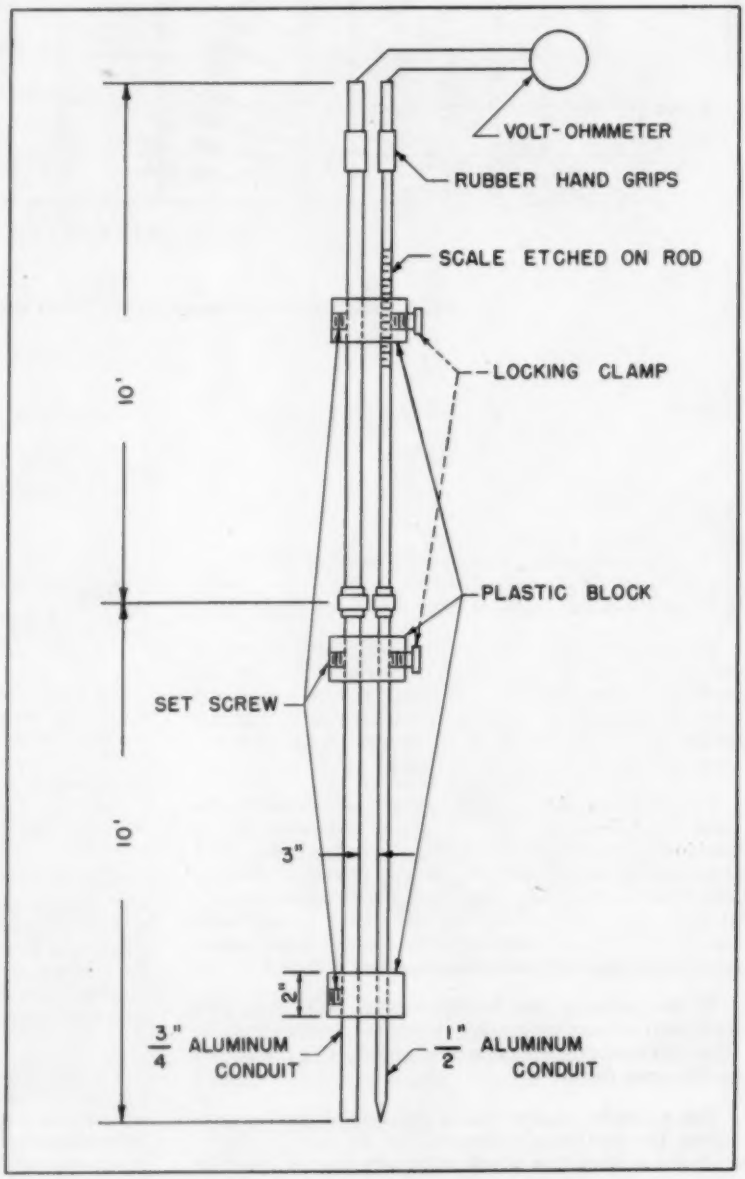


Fig. 1—OHMMETER depth gage, portable type, for flow measurement

coefficient have been determined, a curve is plotted of depth vs. discharge. A hydraulic elements chart facilitates the plotting of this curve. Subsequent gagings require only the measurement of the depth of flow. This depth when referred to the discharge curve gives the flow through the section.

Ohmmeter Depth Gage

A depth gage consists of two conductors insulated from each other—one movable with respect to the other—and an ohmmeter for impressing a voltage across the conductors, illustrated in Fig. 1. The depth of flow is determined by lowering the gage into the manhole until the fixed conductor rests on the invert of the sewer, then raising and lowering the movable conductor until it just makes contact with the liquid surface. The point of contact is determined by a deflection of the ohmmeter needle, which is caused by a coupled circuit, when both conductors are in contact with the liquid. The depth of flow is read directly on a scale mounted or etched on the movable leg of the gage.

Depth gages are made of several types of materials, the ultimate choice depending on the operating conditions. If gagings are to be made at several widely separated manholes, a portable gage constructed from aluminum electrical conduits is most satisfactory.

When many readings are to be made at a single manhole, (especially if the sewer is large and the velocity of flow is high) a gage constructed of galvanized pipe and mounted directly in the manhole is more convenient to use than a portable gage, as in Fig. 2. When using a permanent setup, the depth is read on the staff gage mounted between the two sections of pipe.

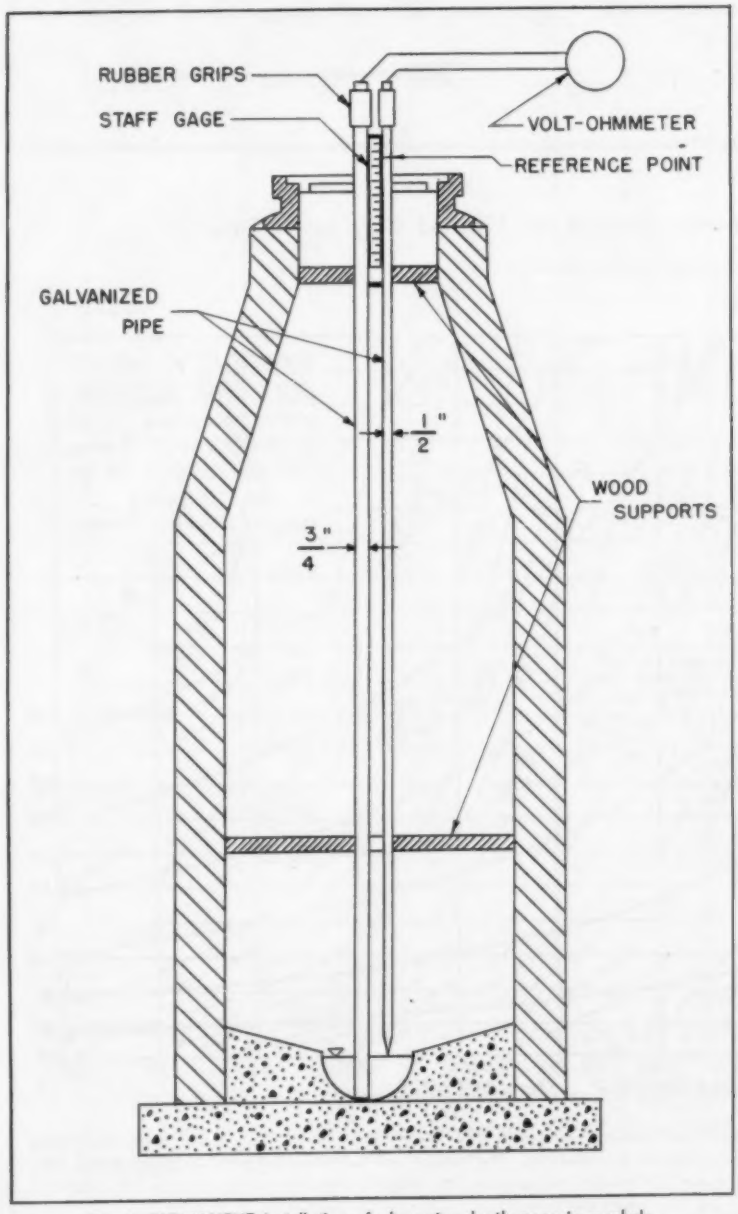


Fig 2—PERMANENT installation of ohmmeter depth gage in manhole

Accuracy of the Method

The accuracy of the method depends primarily on the conditions under which the measurements are made and the care with which the measuring devices are manipulated. In a study at an industrial plant, covering twelve 24-hour periods, the waste discharged from the plant as determined by the ohmmeter technique was compared with the water pumped into the plant (corrected for losses). An average error of ± 5 per cent was observed. The maximum error for a 24-hour period was less than 10 per cent.

Limitations of the Technique

The use of the ohmmeter technique is limited to channel conditions which permit the hydraulic radius to be computed from the depth measurement. Non-junction manholes with a flow channel of the same shape and size as that of the approach sewer will generally meet the aforementioned qualification.

Velocities above about 10 feet per second cause splashing which affects the accuracy of the depth measurement. This interference can be minimized by reducing the sensitivity of the ohmmeter or by shielding the movable conductor.

The depth of the manhole is also a limiting factor because gages more than 20 feet in lenth are difficult to manipulate.

Other Applications of Depth Gage

The ohmmeter depth gage is well adapted to the measurement of the head on a weir. The gage is installed with the bottom of the conductors at the same elevation as the weir crest, and the staff gage is zeroed for this condition. When the movable conductor is raised until it contacts the water surface, the ohmmeter needle deflects and the depth or head reading is made directly on the staff gage. The locking clamp attached to the insulator makes it possible to obtain a more precise depth reading.

Nomograph For Solving Manning's Formula

By PAUL McH. ALBERT

Drury, McNamee and Porter, Engrs., Ann Arbor, Mich.

THE accompanying nomographic chart presents a simple, rapid, and practical means of solving Manning's Formula for the flow of water in pipes and open channels.

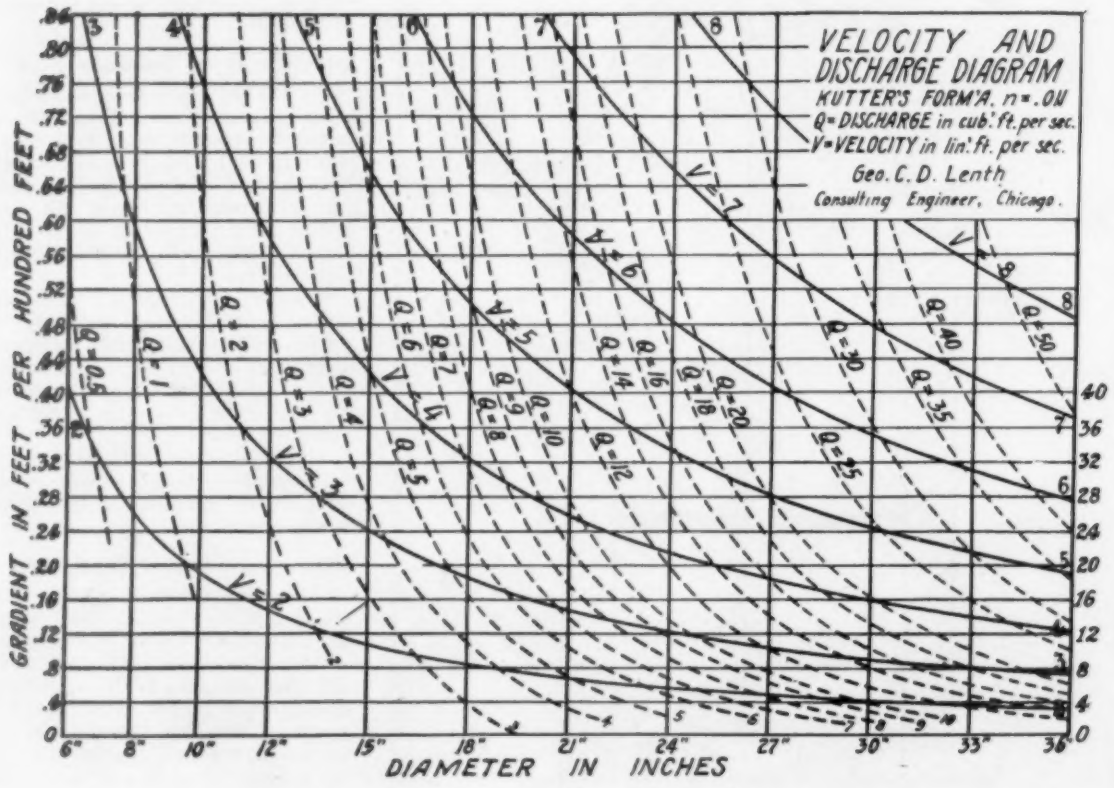
Snap analysis of problems involving this formula will be more accurate and quicker when using this nomograph inasmuch as only two or three motions are required to arrive at an answer.

If the problem entails considerable study, many different solutions may be rapidly tabulated. The effect of the coefficient "n" on the other variables as determined from the nomograph is a valuable aid for the entire range is included.

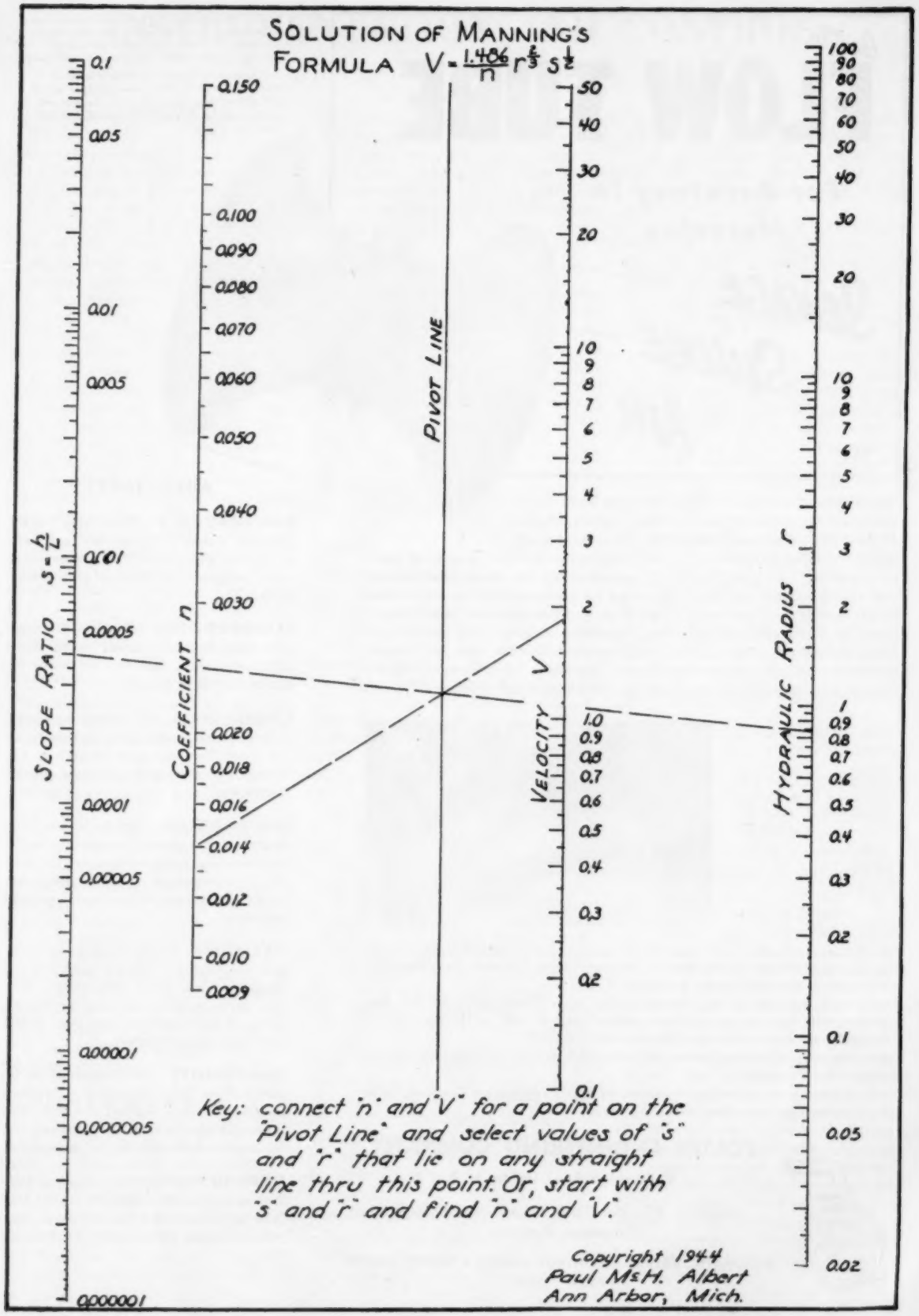
For use in checking previous designs this chart will be found to be valuable and make possible rapid checks inasmuch as it covers a wide range of all the variables. Directions for using the nomograph are given in the key at the bottom of the chart.

Velocity and Discharge Diagram for Vitrified Clay Sewer Pipe

(Courtesy, Clay Products Assn.)


VELOCITY AND DISCHARGE DIAGRAM
KUTTER'S FORM'A, n=.01
Q=DISCHARGE in cub'. ft. per sec.
V=VELOCITY in lin'. ft. per sec.
Geo. C. D. Lenth
Consulting Engineer, Chicago.
GRADIENT IN FEET PER HUNDRED FEET
DIAMETER IN INCHES
6" 8" 10" 12" 15" 18" 21" 24" 27" 30" 33" 36"

(Example: Assume 12 cu. ft. per sec. as the flow to be handled. The gradient for instance, to be a 0.2 ft. per 100 ft. run. Follow to right from gradient figure 0.20 on left until Q12 dotted line is intersected. The vertical line found at that point indicates that a 24 inch sewer is required. Also from the nearest velocity curve V.4 at the intersection it is revealed that the velocity will be 3.8 ft. at full or half full flow.)



Key: connect "n" and "V" for a point on the "Pivot Line" and select values of "s" and "r" that lie on any straight line thru this point. Or, start with "s" and "r" and find "n" and "V."

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Paul McH. Albert
Ann Arbor, Mich.

Gentile®

FLOW TUBE

For Accuracy in Metering

SEWAGE

SLUDGE

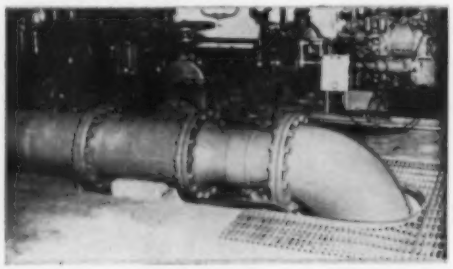
AIR

*Gen-til'-ly

This 78" Gentile Type D Flow Tube of welded steel construction is only 78" face to face, and weighs only 8900 lbs.—many feet shorter and several thousand pounds lighter than a conventional venturi.

It is designed to handle 120 MGD of water at 60 PSIG and 68°F with a maximum head loss of 12" H_2O at these operating conditions, and with an accuracy within ±1% of the calibration curve furnished with it.

The Gentile Flow Tube is an impact-type head meter designed for accurate measurement and regulation of fluid flow. It consists, essentially, of a short spool piece, the inner periphery of which is equipped with two groups of pressure nozzles, one group pointing upstream and the other downstream. The nozzle groups are inter-connected by common pressure rings from which connections are made to the high and low pressure sides respectively, of a conventional indicating, recording or integrating meter. Flow Tubes differ from other variable head meters in that the taps are located at points of equal cross-sectional area. Therefore, the differential developed is a function of the velocity head and independent of the static head.



Actual installation of a 16" Flow Tube for REVERSE FLOW. Note fittings (elbow and tee) are *bolted directly to flanges of Flow Tube.*

Flow Tubes are available in all commercial pipe sizes with welded, flanged, screwed, or other conventional pipe connections. Standard lining is bronze, but other materials such as stainless steels are available.

Flow Tubes are used for the metering of raw water influent, plant effluent, filter effluent, filter wash water, and filter surface wash, as well as for shop tests of hydraulic equipment where accurate results are important.

Flow Tubes can be furnished with or without suitable secondary indicating, recording, or totalizing instruments.

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ACCURACY — Flow Tubes are furnished with head-capacity curves based upon laboratory tests, and can therefore be guaranteed as to accuracy.

COMPACTNESS — No expensive vaults or large areas needed, because Flow Tubes are short. They are only about 1 to 1½ diameters long, depending upon the velocity in the main.

EASY TO INSTALL — Can be installed with no straight run upstream or downstream, except when near valves or regulators. For more difficult arrangements, where extreme turbulence exists, tests may be run simulating actual conditions.

FLEXIBILITY — Can be designed to handle high line velocities with low head loss and reasonably low meter differentials. And, they can be made to give a higher differential for a given diameter ratio than certain other types of head meters.

REVERSIBILITY — It's impossible to install a Flow Tube backwards — upstream and downstream sections are identical. Where system calls for flow reversal, the meter can readily handle the changes.

SIMPLE TO PURGE—where purging or backflushing is a normal routine, the Gentile Flow-Tube can be arranged for constant or intermittent purging without removing from the line.

INSTRUMENTATION AND CONTROL

SECONDARY instruments (or receivers) are devices which convert information sensed by and transmitted from a primary measuring device into observable information. Controls are devices which will receive information sensed by a primary unit and convert it into a control of some mechanical device, operation, or function, such as pumping, chemical feeding, flow regulation, filter washing, etc.

Secondary instruments (flow, level, pressure) are classified in two ways: Type of information desired, and method of transmission from primary to secondary unit. There are three types of information obtainable from secondary instruments, and these are obtainable either separately or in any combination. They are: Indication at the moment (as flow rate, level, pressure, temperature); totalizing over a period (flow); recording a drawn record on a chart as continuous indication of rates of flow, level, temperature and pressure. These secondary instruments are called respectively indicator, totalizer, and recorder.

Transmission

Secondary instruments are also classified according to method of transmission of information from primary unit to instrument. These are mechanical, electrical, or pneumatic. (Pressure is usually transmitted hydraulically.)

Mechanical meters are activated by float or directly by differential pressure. Electrical transmission is used where the receiver cannot be located near the primary unit or for other reasons. Electrical transmissions may be Chronoflo (time-impulse type) or other variations, and is good for any distance. Pneumatic transmission, by a varying controlled air pressure ranging from 3 to 15 pounds, is useful at distances up to 1500 feet. It features a continuous signal and immediate responses.

Summation and Ratio Metering

Two or more flow rates of pumps, mains or filters may be added together to give a total of the combined flow on a single receiver. This addition is accomplished by means of a summator (electrical or pneumatic) which receives the several sensed data and transmits the sum of the individual data. Ratio transmitters can be used to receive two different flows and calculate and transmit the ratio to a secondary instrument. This device is used in activated sludge plants to determine and indicate or record the air/sewage ratio and the return sludge/sewage ratio.

Receivers

In flow measurement, the flow varies as the square root of the head in the primary device. The receiver is designed to convert this information into the desired units. Charts or scales may be of the square root type with the divisions spaced according to the square of the unit. Readability is best at the high end of the scale. Linear type receivers have scales and charts with divisions spaced equally. Accurate readability is obtainable at both ends of the scale.

Controls

Flow measurement can be used to provide control of flows, chemical feeding, proportioning, pumping, sampling. Mechanical, electrical or pneumatic means can be used for control purposes.

Filter effluent controllers are available in two designs, self-powered, direct-acting; and hydraulic cylinder operated. They are used to maintain a constant rate of filtering regardless of loss of head as filters become dirty. Wash water controllers are similar to filter effluent controllers and are used to control the rate of filter back washing.

Auto-central control is a centralized system which automatically controls the rewash cycle of filters in sequence and can be initiated manually or by loss of head in the filters.

Chemical feed can be paced proportionally to flow at a fixed dosage rate, or by programmed schedule, or by timed-cycle. Sampling can likewise be controlled according to proportional flow, program, or time-cycle. Reservoir and elevated storage can be controlled by float or pressure sensing devices which control pumping. Distribution system flow can be controlled according to a combination of pressure and flow rate. (Pressureflo system.)

Operating Tables and Panels

Secondary instruments, also called receivers, or gauges, may be mounted in several ways. Loss of head gauges, rate of flow gauges, sand expansion gauges, and controls for filter operations are usually placed in a filter operating table. Wash water, and summated flow gauges are often hung in the filter gallery.

In centralized control, filter gauges, flow gauges, pressure gauges, and other types of receivers are placed in a single panel along with switches and controls, all of which may be located in the superintendent's or operator's office.

In sewage treatment works, flow measurement, disinfection, sludge measurement, sludge digestion pumping and withdrawals, sludge dewatering, elutriation, flow ratio-metering, and weighing of vacuum dewatered sludge all employ instrumentation and control. As in a water works, instruments and controls are frequently located in centralized panels, either in the operator's or superintendent's office or some other central location.

In both water and sewage works, centralized control reduces the work load on operating personnel, improves controls of operation and reduces operating costs.

Selection of Instruments and Controls

In the choice of secondary instruments there are a number of factors to be considered and many questions to be answered. In flow measurement, the type of primary device selected (weir, Parshall flume, Venturi tube, Dall flow tube, nozzle, orifice, etc.) dictates the method by which the secondary instrument or control is operated. The range of maximum to minimum flow must be known.

Accuracy depends not only on the primary device and the receiver but on the particular combination chosen. The relative location of primary device and secondary receiver has a bearing on the type of transmission used.

Choice of secondary instruments depend also on type of information desired, capacity of present plant, future capacity, and life expectancy of the equipment. Choice of primary and secondary instruments also have a bearing on control systems selected.

Selection of control systems and devices depend on the function, equipment, or operation to be controlled as well as the primary device, secondary instrument and system of control desired.

Maintenance of Filter Instruments

Routine maintenance, part replacement and new equipment are required to operate 80 filters in Chicago's South District Water Filtration Plant

by TIMOTHY D. NULTY

Water Chemical Engineer, Bureau of Water, Dept. of Water and Sewers, Chicago, Ill.

THE first of the 80 filters of Chicago's South District Filtration Plant were placed in service February 22, 1947. By May of 1947 all water leaving the plant was filtered. The last filter was placed in operation November 13, 1947. These filters have operated continuously since that time except for the period from January 18, 1952 through January 31, 1953 when, for the purpose of obtaining data pertaining to high rate filtration, only 50 filters were used. During this particular period, 12 fixed rate filters were kept in continuous operation and the remaining 68 filters were rotated in and out of service to divide the time in service equally.

Over this 7-year period a certain amount of maintenance work has been necessary to keep the instruments and appurtenances connected to the filters in operation. The largest number of manhours of work has been expended on routine maintenance, such as packing and adjusting sealing glands, cleaning screens and filters, and lubrication. The next largest expenditure of manhours has been in replacing worn or defective units or parts of units. In addition, several pieces of equipment have been installed to minimize the amount of maintenance work.

Soft Water Not Needed

Some equipment of this type was installed with the original equipment in the plant. Water softeners were installed on the low pressure hydraulic lines which operate the filter rate controllers. The first softeners were of insufficient capacity and were replaced by larger softeners. The latter gave trouble by passing salt into the discharge, causing the pilot valves on the rate controllers to clog. Use of the softeners was discontinued in 1950, and ordinary process water has been used up to the present time without difficulty.

Removing Air from Oil

Another piece of equipment that has given trouble is the electrodryers located on the +6 floor on the west side of the filter building. The purpose of these electrodryers is to remove oil and moisture from the compressed air used for the operation of the instruments connected to the filters. It is necessary to remove the oil from the air for it tends to collect at the various tiny needle and ball check valves located at several points in the system and render them inoperative.

At the east end of each filter gallery a cellulose filter was added to the air supply line to aid the electrodryers. Even after this addition was made, some oil and moisture managed to pass, requiring still another electrodryer unit (an Electro-Filter), which was installed recently. (See Fig. 1) The air supply to the instruments now seems to be reasonably free of oil and moisture.

An Emergency Air Supply

In the early days of operation there were occasional failures in the air supply to the filter controls. (The air is drawn from the plant air-system, supplied from compressors in the boiler room.) The automatic filter rate controllers depend on the back-pressure in the air system to maintain the required filter rate. When this back-pressure drops to zero, these rate controllers operate to their maximum capacity and cause danger of overflowing the filtered water reservoirs.

In the first effort to overcome this hazard, air-storage tanks capable of supplying the needed pressure for three hours were installed in each filter gallery. Between each tank and the air supply system, check valves were installed. Should the air pressure fail, the tank supplies air until the system is again placed in normal service. The tank air pressure is at 100 lb. per sq. in. This is first reduced to 18 lbs., and then to 3 lbs. for application to the filter controls.

As a secondary safeguard, diaphragm valves, counter-weighted and

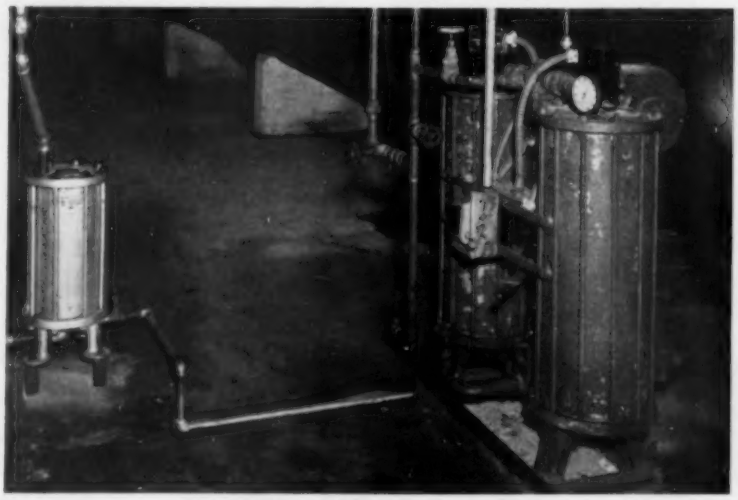
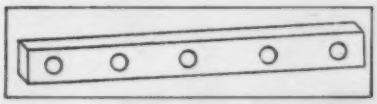


Fig. 1—OIL-FREE-AIR to operate instruments
Provided by combination of additional Electro-Filter and Electro-Dryer units



SKETCH illustrating original construction of copper high pressure water manifold

with the spring tension set to close at 10-12 lbs., were installed between the 18 lbs. and 3 lb. pressure reducing valves in each gallery. Should the air pressure drop below the set point, the diaphragm valves close, locking the automatic rate controllers at the rate then prevailing. These diaphragm valves are carefully checked once each shift so as to be sure they are in an operable condition.

Filter Gallery Dehumidification

In addition to the original equipment, whose prime purpose was to minimize maintenance, more equipment has been added over the period of 7 years for the same purpose. The most extensive of these additions are the 3 Kathabar units used for the dehumidification of the filter galleries and the west pump room. Two previous articles in the Bureau's monthly "Pure Water" publication, "Dehumidification of Pipe Galleries at the South District Filtration Plant" by Mr. F. G. Gordon (July, 1951), and "Dehumidification at the South District Filtration Plant" by Mr. Arthur Horwitz (October, 1951), cover this subject very thoroughly.

Leaks in High Pressure Lines

The large filter valves are operated by high pressure hydraulic water which is controlled by means of 4-way valves in the filter operating table located on the gallery side of the filter on the operating floor. Each filter table contains five 4-way valves which are connected to a supply and a discharge manifold. Some troubles have been encountered with the 4-way valves leaking and sticking, but most of the time the trouble has been remedied by cleaning the old lubricant from the valve and relubricating.

The most serious trouble in this particular part of the filter appurtenances has been with the hydraulic water manifolds developing leaks. The original copper manifolds were made as shown in sketch "A." Due to the fact that these manifolds were made in one piece, when a leak occurs, it is necessary to remove the entire manifold to repair it. This old type manifold is now being replaced by one made up of several small pieces of round copper tubing with soldered fittings.

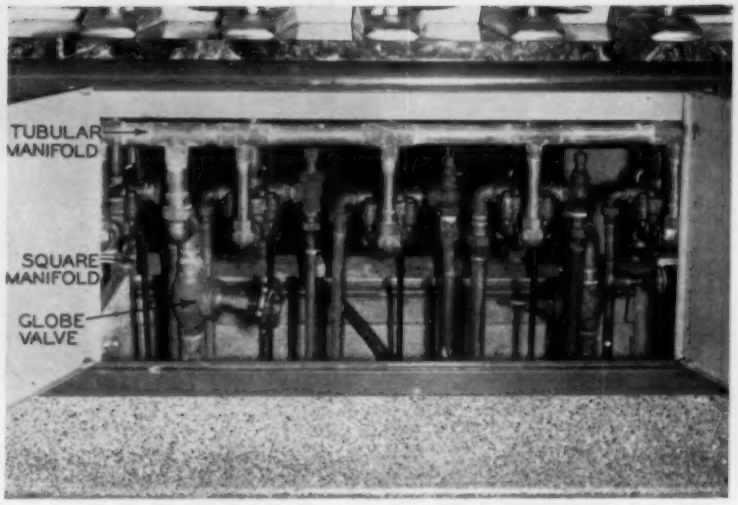


Fig. 2—NEW TYPE MANIFOLD made of copper tubing with soldered fittings
Easier to repair—replacing original single piece units

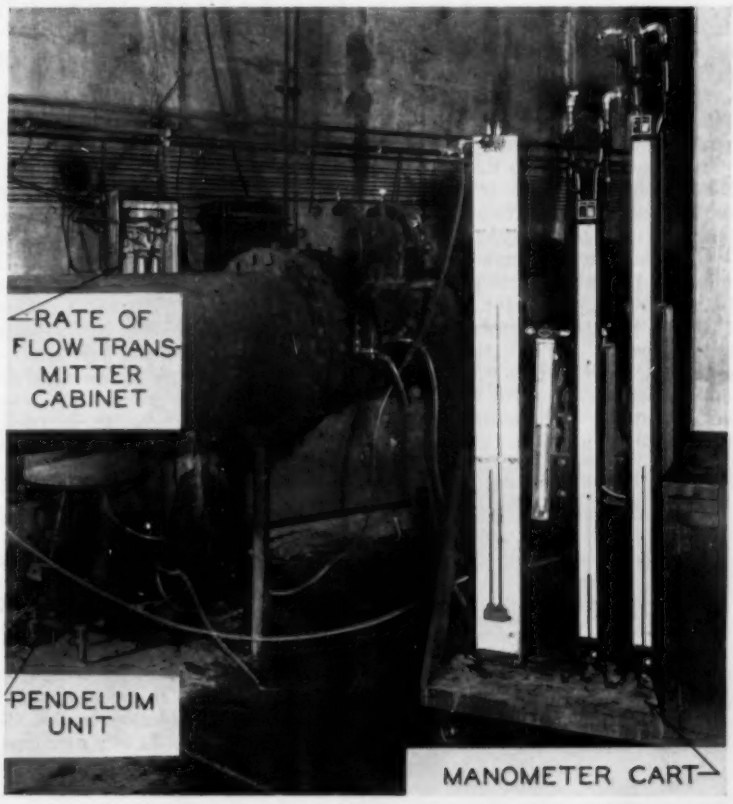


Fig. 3—PENDULUM UNIT positions rate controller valve, and manometer cart
Providing series of calibration test instruments

The new type manifold has 2 advantages over the older type: (1) when a leak develops only that portion of the manifold having the defect must be removed and replaced. (2) the location of the new manifold in the filter table permits work to be done on the 4-way valves more easily. As of the writing of this report, 31 new type manifolds (See Fig. 2) have been installed. As more old manifolds develop leaks they will be replaced.

Globe Valves Replace Gates

On the original installation, the hydraulic water supply lines had a 1½-in. shutoff valve, located under the filter tables, which was a gate valve with a small hand wheel. This valve was found to be very unsatisfactory in that the 135 lb. pressure (maximum) on this line was causing severe wire drawing on the valve seats and discs and in addition the operators were having trouble opening and closing the valves due to the size of the handwheel. All 80 of these valves have been replaced by globe valves with large handwheels which seem to be functioning properly. (See left side of Cabinet in Fig. 2)

Filter Control Diaphragm Corrosion

Each filter is equipped with a diaphragm operated pendulum unit which governs the position of the butterfly valve in the rate controller. The most prevalent source of trouble in the unit is with the diaphragm rupturing. To date, 33 diaphragms have been replaced in the pendulum units. One other trouble encountered in these units is with the small pilot valve sticking. However, this trouble is very easily remedied by cleaning the plunger rod.

The water supply to this unit and the discharge to the rate controller must pass through strainers. These strainers must be cleaned periodically to maintain proper operation of the unit. To prevent excessive corrosion of the bottom side of the diaphragm chamber, these units are being raised approximately 2-in. off the floor by extending the legs. This work is being done when a diaphragm is replaced, and to date 33 of the units have been raised. (See Fig. 3)

Low Rate Filter Operation

Two adjustments on these pendulum units have been found to give better operation. As first installed, there was a tendency for the automatic filters to shut off entirely when the demand rate dropped below 2.5 mgd per filter. By adjusting the long connecting rod between the diaphragm and the bellows to its full effective length, these filters now continue to operate at rates as low as 1.3 mgd. The second adjustment was on the tension applied to the diaphragm. This was formerly set with the rate controller manually fixed at zero. This gave what is called locally a "Dead Zero." This means the rate controller when showing "zero" could just be locked against the zero pin with some flow still occurring. By adjusting the tension with the rate controller set manually at 3 mgd a "Floating Zero" is obtained. With this adjustment when the rate controller indicated zero there is no flow.

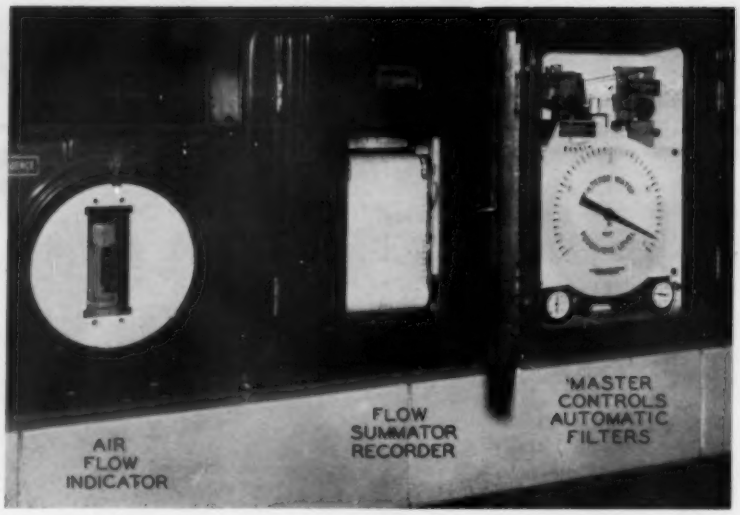


Fig. 4—AIR FLOW INDICATOR panel recording flow summator and master controls for automatic filters

Maintenance of Instruments

The last equipment to be dealt with in this report are the filter instruments. Each of the 80 filters is equipped with a transmitter and a receiver for the loss of head, the rate of flow and the sand expansion gauges. The rate of flow and loss of head transmitters receive two different water pressures and transforms the difference in these two pressures to air pressure which in turn is transmitted to the receivers. The sand expansion transmitter receives a differential air pressure which is transmitted to the receiver. One can readily understand the necessity of a continuous supply of clean, dry air which was mentioned previously.

The rate of flow and loss of head transmitters (See Fig. 3) have required more maintenance, other than routine maintenance, in that some of the Lucite mercury wells have developed cracks due to thermal expansion and contraction, causing loss of mercury, thereby delivering incorrect results to the receiver charts. As these wells develop cracks, they are replaced by wells of a new design which so far have not shown any evidence of cracking. To date, 18 of these wells have been replaced and it is expected that all 160 will have to be replaced within the next few years.

Another part that is beginning to require replacement is the small diaphragm which operates the transmitter. After 7 years of operation they are beginning to rupture. Approximately 10 diaphragms have been replaced thus far.

Calibration Manometers Are Portable

For routine calibration of the rate of flow and loss of head instruments a series of manometers have been installed on a cart for mobility. (See Fig. 3) The manometers are valuable in checking the rate of flow and loss of head recorders.

In addition to the individual filter instruments, there are flow summators which indicate and record the flow through 40 filters. Each gallery also has its own backwash water rate of flow indicator and recorders as well as a rate of flow indicator and recorder for the surface wash water. These last mentioned instruments require very little maintenance, but occasionally a diaphragm or a cracked mercury well must be replaced. Figure 4 shows air flow indicator, recording flow summator (for 2 galleries) and master controls for automatic filters.

Multiply Replacements by Eighty!

This report does not mention parts of the filter such as the sand and gravel bed, the under drainage system, the surface wash system, the wash water troughs or the five large gate valves. It has been the aim of the writer to point out the exceptional problem of maintenance work over and above normal maintenance which has been, and still is necessary where such a large number of filters are being operated. No matter what part is found defective, one can multiply the number of manhours necessary for one such replacement by 80.

The writer wishes to extend a note of thanks to Filtration Engineer, Mr. Carl Chevedden, who was of great help in the preparation of this report.

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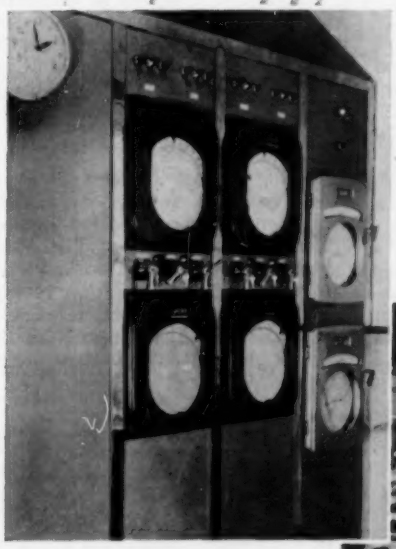

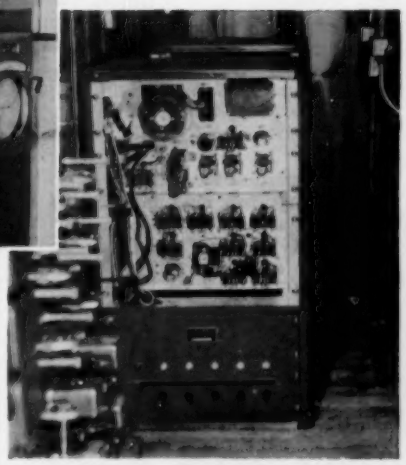

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Remote Control in Water Systems*

E. WYLIE HEAD

Sales Mgr., Control Corp., Minneapolis, Minn.

DURING the past several years the terms "supervisory control" and "telemetering" have been heard more and more frequently in the water works field. Supervisory control is the control of equipment at a distance and the supervision, by means of signals, of the status of this equipment.

Supervisory control and telemetering were first used on a limited scale by the electric utility industry in the late 1920's. Since World War II this industry has made extensive use of such equipment, and most sizable utility systems have some in service. At present there are several water systems using supervisory control and telemetering. Operations usually performed by supervisory control include the starting and stopping of pumps and the opening and closing of valves. Operations performed by telemetering include remote meter readings of tank or reservoir levels, pressure, and flow. Both supervisory control and telemetering can be used to control various pump programing schedules.

Reasons for Use

There are three principal reasons why there is such an increasing interest in these two items by water works engineers. The first, and perhaps most important, cause is the increasing cost of labor at pumping stations and similar installations. The labor costs of manning a station for 1-2 years will usually pay for sufficient supervisory control and telemetering to eliminate manual operation of such a plant.

A second reason for the trend toward this type of equipment is improvement in service. Where two or more plants have to be coordinated for proper operation of the system, this can usually be done better by centralized control under one operator. With such a system the central operator has complete facilities to perform any necessary operations at remote locations and has adequate information on what every unit in each remote station is doing.

A third reason for the growing use of this type of equipment is labor unreliability. During periods of labor unrest, it may be unwise to depend upon local operators at the various plants comprising a system. Operators employed at a centralized dispatching location, however, are generally not affected by labor disturbances.

There are several factors to be considered in designing supervisory control, the most important one being reliability. It goes without saying that the components used in the equipment should provide a reasonable period of trouble-free operation. Aside from this, the most important consideration is the protection provided by the equipment against operation by signals that do not originate in supervisory control mechanisms. Examamples of such signals would be those caused by cross talk, switching surges, lightning. The equipment can reasonably be expected to encounter some types of spurious signals during its life. The improper operation caused by such signals would be at least annoying and could be disastrous in basic pumping stations.

Types of Supervisory Control

During the last 20 years, two primary types of supervisory control equipment have been evolved by three different manufacturers. The older of these types is known as "impluse" supervisory control. In this system, all operations, both remote control and supervision, have signals in the form of short electrical pulses, somewhat similar to those obtained in telephone dialing. If it is desired to operate remote equipment, a button is pushed which transmits a certain combination of these pulses to the remote location. The manufacturers of this type of equipment recognize that a short pulse of electrical energy can be easily duplicated from external sources, and it is required that the remote-location equipment transmit an equivalent grouping of pulses back to the originating or controlling station. If the combination of pulses coming back agrees with the one going out, the operator is allowed to transmit and operate a signal composed of a short grouping of impulses. This system, known as a "checkback," is a necessary part of any impulse system to provide minimum protection against spurious signals.

In place of control impulses easily duplicated from other sources, a system composed of a sequence or combination of audio-frequency tones has been evolved. In place of using the one checkback feature of the impulse system, automatic checking of the signal is provided at the remote location as it is received, with six different checks necessary before an operation is allowed to take place. In this "audiosequence" type of supervisory control, all remote control signals are composed of a minimum of three (usually four) audio frequencies transmitted one at a time in a

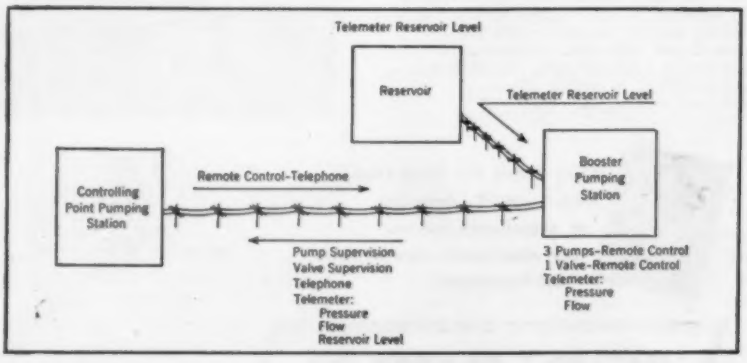

Fig. 1. Installation at Lake Forest, Ill.

A single pair of leased telephone wires serves for telemetering, controlling, and telephoning.

* Reprinted from June AWWA Vol. 47, p. 433 (1955), by permission.

definite sequence. The resulting operation depends only upon the sequence or order in which the tones are transmitted. Audio-frequency tones usually used for remote control are 210, 310, 350, 390, and 430 cycles. As this combination of audio-frequency tones is received at the remote location, the six checks previously mentioned are imposed. The first check measures the number of audio frequencies and requires that this number b ecorrect before an operation is allowed to take place. In place of a random electrical impulse, the frequencies must be correct within 3—4 cycles or no operation is allowed to take place. The frequencies must arrive in a definite, restrictive sequence that corresponds to preset combinations. No operation is allowed to take place if two frequencies come in simultaneously, and the interval between frequencies must not exceed a predetermined limit. In addition, no frequency can immediately follow itself.

In considering the various possibilities for spurious signals that might be encountered during the life of the equipment, it can be readily seen that the six checks effectively rule out any chance of incorrect operation. The audio-sequence system allows generally faster operation than can be obtained with the impulse system. Wide use throughout the United States, Canada, and Mexico attests to audio sequence reliability.

Forms of Equipment

Supervisory control equipment can be in many patterns and operate over several different types of channels. The controlling-or dispatching-station equipment can take the form of a switchgear type of cubicle, a wall-mounted cabinet, a desk, a bench-board, a system diagram on a large panel, or various other aspects that might be most suited to a particular application. In general, the equipment at the controlled end is housed in cabinets or cubicles of various sizes and styles. The panel at the controlling location is usually composed of a group of bakelite rectangles known escutcheons. An escutcheon provided for each piece of remote equipment being controlled or supervised comprises three lamps to show the status of the equipment, an operation selector switch, and an operating-lever key. In some cases this lever key takes the form of a push button. If telemetering is associated with the equipment, the appropriate indicating or recording meters are placed above or below the control panel.

Telemetering, if used, takes one of two forms. The telemetered measurement value can be brought in continuously and usually will operate a recording instrument. Where the readings may not be required continuously, the supervisory control equipment will select any desired measurement and bring it in as required. Almost any number of such selections can be made, one reading at a time being brought in to appear usually on an indicator. The channel connecting the central controlling location with the one or more remote stations can take several forms. Often this is a pair of telephone wires, either leased or owned by the user. The wires can be one of several pairs in a telephone cable or can be a pair of open telephone wires. Microwave radio is now being used more often as a connecting channel. It is generally possible to control almost any number of operations in one or more plants over one pair of wires or channel. In addition, it is possible to bring back a large number of lamp indications from remote locations, as well as a large number of telemeter readings, over the same pair used for remote control of the station or stations. In addition to supervisory control and telemetering signals on a pair of wires, it is fairly common to have this same pair also used for telephone.

The possibilities involved in the use of supervisory control and telemetering are many and varied. In general, standard, proved circuits and components are used to build equipment to the specific requirements of each user.

Four Specific Installations

Four applications of supervisory control and telemetering to the control of water systems are described in the remaining part of this paper. The first of these is used by the city of Lake Forest, Ill., and was installed in 1951. Figure 1 is a diagram of the system. The controlling-station equipment is mounted in an older pumping station, and it is used to control three pumps and one altitude valve in a new booster pumping station over a pair of leased wires. Water to the booster pumping station is from a nearby reservoir. Water level measurements are transmitted over the same pair of wires used for control. From the booster pumping station itself are telemetered one pressure and one flow value. Telephone currents are also sent over the same pair of wires. The supervisory control equipment is so arranged that at a later date automatic pump programming may be incorporated.

Another installation is at Aberdeen, S.D., also set up in 1951. This involves a central controlling point located at the city hall. Water level information from an elevated tank is telemetered into the city hall and then to the booster pumping station. The operator at the city hall has a reading in front of him at all times showing the water level in the elevated tank, as well as water level in an underground reservoir, where a reading is sent over a separate pair of wires to the filter plant. The operator also has a telemetering instrument giving him the flow rate at all times from the booster pumping station. The elevated-tank water level information which is brought into the city hall and extended to the booster pumping station is used to control an automatic pump-programming

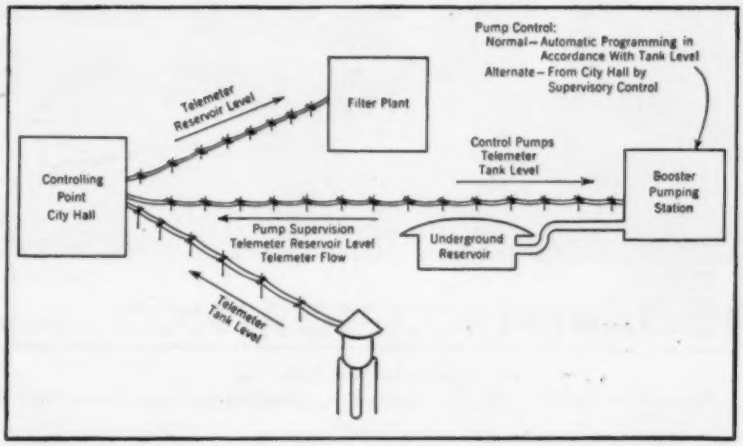

Fig. 2. Installation at Aberdeen, S.D.

An operator at city hall can tell at a glance the status of every part of the system, and can control any desired operation.

unit. The appropriate pumps are operated in accordance with water level in the elevated tank. The operator sees which pumps are running at all times by means of lamps on the control panel. He has the option at any time of taking control away from the automatic programming equipment and directly operating any or all pumps by supervisory control. Figure 2 illustrates the layout of the various elements in this waterworks system.

The third installation is used by the Dallas County Park Cities Water Control and Improvement District No. 2, and is located near Dallas, Tex. The controlling station is in a section of the treatment plant. On the operator's control and supervision desk are provided control escutcheons for three stages each of four different pumps in the treatment plant. The meter panel also shows data for the treatment plant: raw-water flow, clear-well level, treated-water flow, treated-water discharge pressure, and raw-water pump well level.

Water level information from four different elevated tanks is telemetered to the controlling operator, as well as flow data from the meter station. The operator has direct control of four different pumps in a booster station and knows at all times which pumps are running and which are not. As in all supervisory control, any shutdown of a pump by the protective equipment will immediately notify the operator by means of an audible alarm and a change in lamps which calls attention to the actual unit that has changed its condition. Figure 3 illustrates the layout.

The fourth water works system is that of Fort Lauderdale, Fla. The project there involves a telemetering of water level from five different tanks, located adjacent to the central-dispatching station, to each of two pumping plants. At each plant recording instruments provide a continuous record of the water level in the tanks. From the central-dispatching station, line pressure values are continuously telemetered. In addition to the direct recording of the pressure at each plant, this value is telemetered to the other plant and the central-dispatching station. at one plant automatic control of pumps is achieved by telemetered water level indications. From a fourth location water level information in the tank is telemetered to one of the pumping plants and used to operate supervisory control equipment which controls pumps in a well field located elsewhere. The seven values telemetered to each of the two pumping plants are all carried over one common pair of wires. In no case is more than a single pair of wires used except for the control and supervision functions connecting the well pumps in the field to the well field supervisory control cabinet.

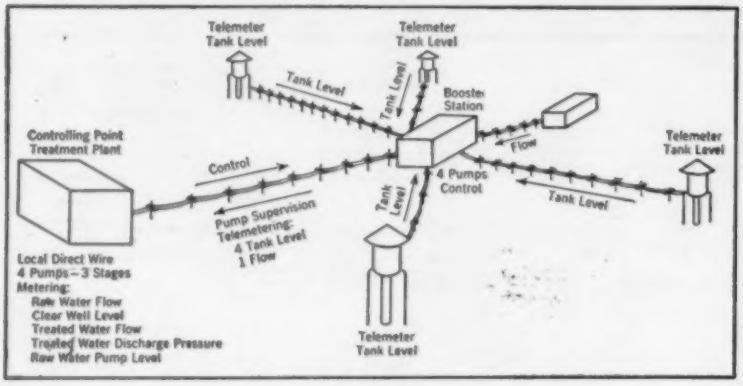

Fig. 3. Installation Near Dallas, Tex.
The centralized control of this plant results in substantial savings in manpower costs.

Conclusion

From the few applications described, it may be seen that supervisory control and telemetering can be combined and applied in a wide variety of ways. In each case the application of this equipment has resulted in important savings in man power and has contributed greatly to better and more efficient operation of each of the water works systems. The elmination of operators at a normally attended station, or the elimination of the need periodically to send operators into a station, can result in substantial savings in man power costs. Use of supervisory control and telemetering, in combination with automatic equipment where needed, can result in much more efficient operation of any water works system.

★

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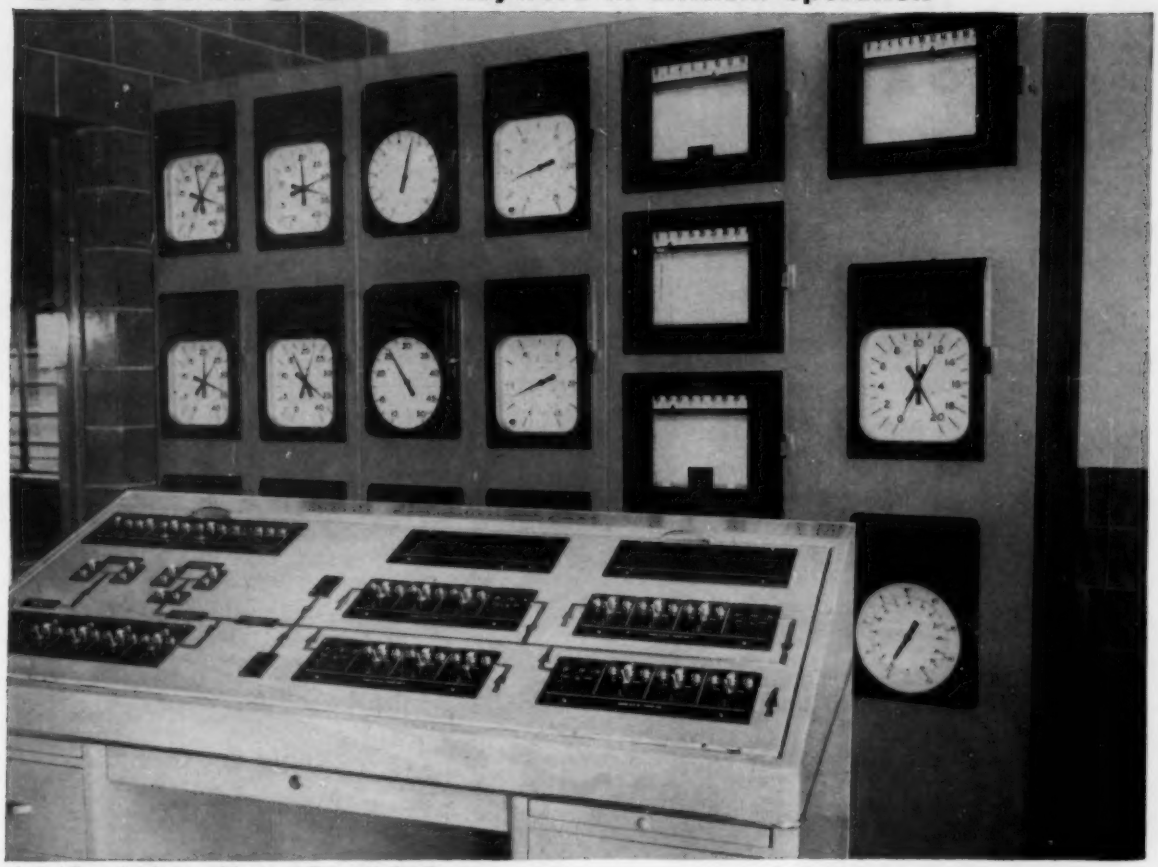

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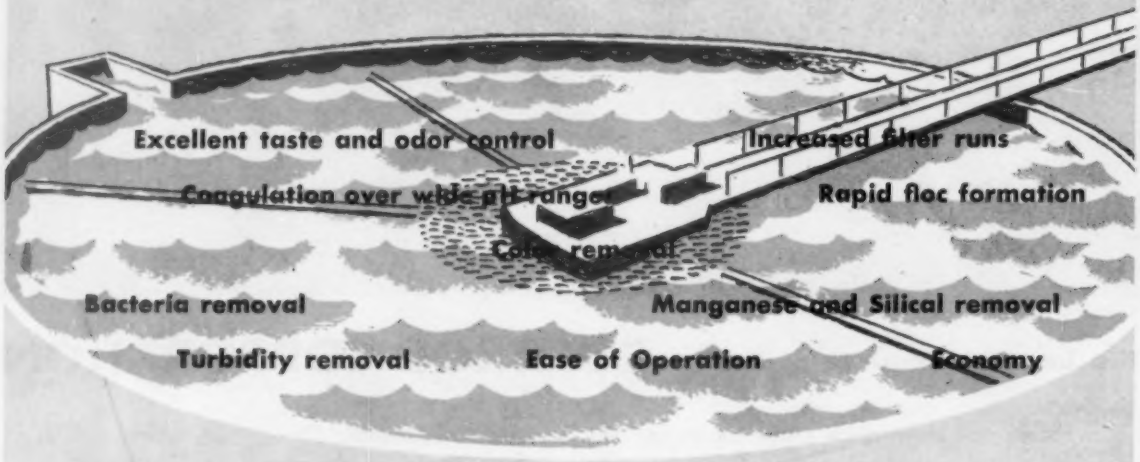

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CHEMICAL HANDLING AND FEEDING

IN THE FIELD of water purification and sewage treatment, there are a number of treatment processes which involve the use of chemicals. Therefore handling and feeding of chemicals is an important subject to the water or sewage plant operator. The following outline covers the subject and the wide range of phases it embraces. In addition to articles which appear in this section, the reader is referred to the publication of chemical companies and chemical feeder manufacturers for bulletins on specific chemicals and equipment.

I. . Chemicals

A. Shipping Data
  1. Available Forms
  2. Containers and Shipping Requirements
    a. Dry Chemicals
    b. Liquids and Solutions
    c. Gases

B. Characteristics
  1. Appearances and Properties
  2. Bulk Density
  3. Commercial Strength
  4. Solubility

C. Unloading and Storage
  1. Dry Bulk Chemicals
  2. Packaged Dry Chemicals
  3. Liquids and Solutions
  4. Liquefied Gas

D. Handling
  1. Materials for Handling
  2. Transfer to Feeders

E. Safety
  1. Non-toxic Chemicals
  2. Toxic Chemicals
  3. Corrosive Chemicals
  4. Other Hazards

F. Types of Control
  1. Manual
  2. Semi-automatic
  3. Programmed
  4. Proportional
  5. Automatic

II. . Chemical Feeders

A. Types of Feeders
  1. Volumetric
    a. Oscillating Plate
    b. Oscillating Throat
    c. Rotating Disc
    d. Star
    e. Screw
    f. Ribbon
    g. Vibrating
    h. Miscellaneous
  2. Gravimetric
    a. Continuous
    b. Semi-continuous
    c. Loss-in-weight
  3. Solution
    a. Non-positive displacement
      (1) Decanter
      (2) Orifice
      (3) Rotameter
      (4) Crystal Solution
    b. Positive Displacement
      (1) Rotating Dipper
      (2) Proportioning Pumps
  4. Gas

B. Accessories
  1. Hopper Agitators
  2. Dissolving Chambers
  3. Bucket Elevators
  4. Dust Collectors
  5. Instruments and Control

C. Preventive Maintenance
  1. Tools
  2. Spare Parts
  3. Lubrication
  4. Records
  5. Repair

III. . Chemical Feeding

A. Definitions
  1. Dosage
  2. Feed Rate
  3. Solution Strength

B. Treatment Processes
  1. Water
    a. Coagulation
    b. Disinfection
    c. Fluoridation
    d. Softening
    e. Taste and Control
    f. Miscellaneous
  2. Sewage
    a. Coagulation
    b. Disinfection
    c. Odor Control
    d. B.O.D. Reduction
    e. Sludge Dewatering

C. Control
  1. Chemical Analysis
  2. Instrumentation
  3. Problems

Guides for Selecting Chemical Feeders

By PAUL A. COFFMAN, JR.
Chief Engr., Omega Machine Co., Providence, R. I.

AT some time in his career, nearly every waterworks operator is faced with the problem of designing a chemical feeder installation, and of selecting and purchasing the equipment. The final success of the feeder installation depends largely upon the thought and study given to the problem before equipment is purchased.

The science of handling and proportioning chemicals for water treatment has advanced to the point where standard equipment is available from several manufacturers for solving practically any feeding problem. The choice or selection of chemical feeding equipment to fit a particular situation likewise can be standardized within certain limits, and it has been possible to develop guides for the selection of this equipment.

Once the water treatment process to be used has been decided on with competent technical advice from the consultant, it is time to select chemical feeding equipment. Such advice should include a decision as to the chemical to be used, whether it will be fed in dry or liquid form, the point of application, and due consideration of availability, cost, quantities to be handled, solubility and stability of the chemicals which can be used.

This paper deals with guides for the selection of dry chemical feeding equipment. A future paper will deal with liquid feeding equipment. There are eight principal guides for selecting dry chemical feeding equipment.

Guides for Selecting Dry Chemical Feeding Equipment

1. Define
Operational Requirements

2. Determine
Storage Capacity Required

3. Choose
Best Available Location

4. Choose
Type of Installation

5. Choose
Type of Feeder Preferred

6. Select
Accessories Desired

7. Furnish
Information for Manufacturers

8. Evaluate
Proposals Submitted

Guide No. 1—Define Operational Requirements

1. Determine the feed rate requirements for the installation. It is important to give careful consideration to the actual maximum and minimum rates of feed required. If minimum and maximum rates required are not carefully determined, equipment manufacturers may be forced to offer larger or more expensive equipment than is actually needed for the job.

2. Decide on the degree of accuracy required. If the process is critical and chemical feeding must be precise, a per cent plus or minus tolerance is probably all that can be allowed and gravimetric feeders must be used. On the other hand, if the chemical treatment required can vary some, without seriously affecting the process and a considerable retention period is available for ironing out variation in dosage, then a feeding accuracy varying from three to five per cent from the selected feed rates may be satisfactory, and volumetric feeders can be used.

3. Decide on the records which will be required for this process. If it is desirable to have totalizers and recorders, then gravimetric feeders should be specified. A log sheet record can be had with volumetric feeders provided they are installed on platform scales. If no scales are furnished, then the only reliable record will be an accurate count of bags of material used on a daily basis. For very low feed rate installations, the bag count method will not be satisfactory because only one or two bags of chemical will be used in a twenty-four hour period.

4. Decide on the type of controls required for the installation. This includes a decision on whether the equipment will be manually controlled or automatic. If the rate of flow through the water plant varies considerably, then proportional pacing may be required. If the feeder installation is for a well station, automatic start-stop control in parallel with pumps may be desirable. For some installations where the feeder is to be in-

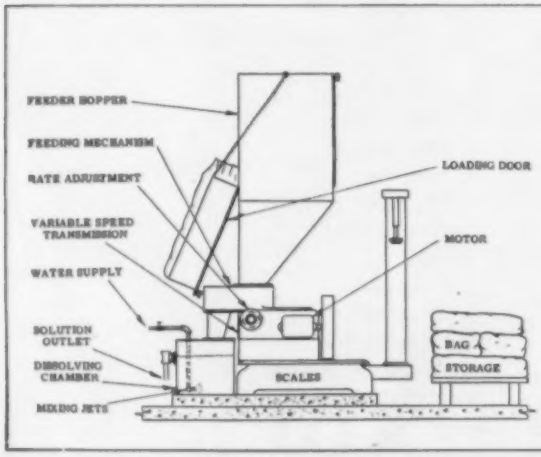


Fig. 1—Small unit feeder installation
Low feed rate—small chemical storage.

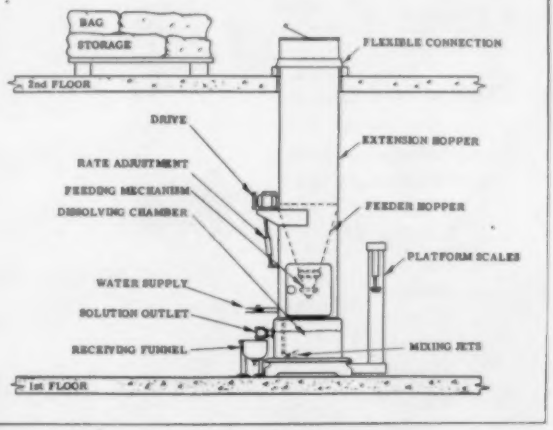


Fig. 2—Two floor feeder installation
Low or high feed rate—second floor chemical storage.

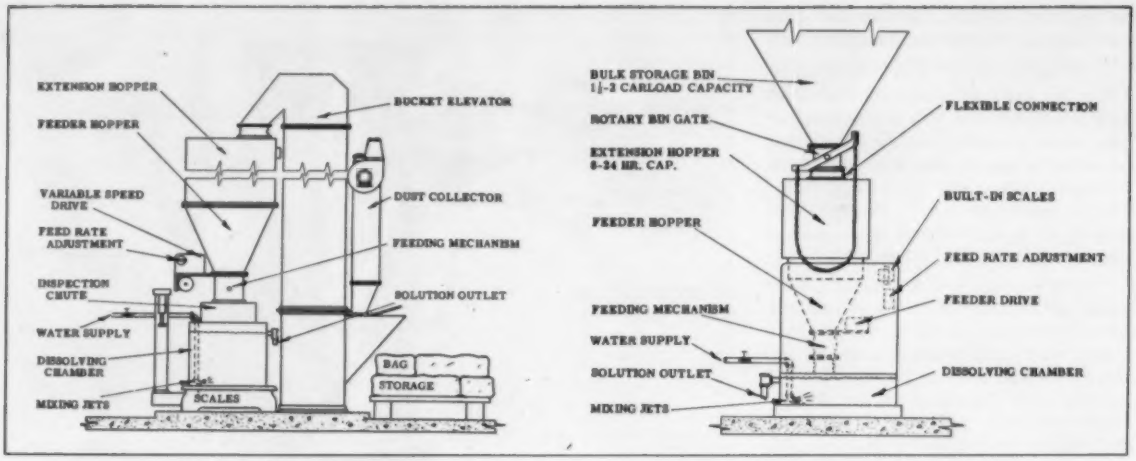


Fig. 3—Mechanical loading installation
High feed rate—large hopper capacity.

Fig. 4—Bulk storage feeder installation
Low or high feed rate—storage in overhead bins.

stalled in a rather isolated location or where manpower is limited, remote control of the feeding equipment may be an economic necessity.

Guide No. II
Determine Storage Capacity Required

1. Storage in a chemical feeder installation is an important consideration from the standpoint of labor saving and purchase of chemicals in economical quantities. All feeders should have an initial hopper capacity, equivalent to not less than four nor more than twenty-four hour storage when feeding at the maximum required rate of feed. If manpower for dumping chemicals is available on all three shifts, then four to eight hours capacity will be satisfactory; otherwise, provide capacity for twenty-four hour operation.

2. Bag or bulk storage capacity must be determined on the basis of economical purchase and transportation quantities, and time required for delivery from suppliers. Sixty to ninety days' supply is the usual bag or bulk storage requirement. If the chemical is to be stored in bags, due consideration must be given to the floor space required for such storage and means for handling the bags in the most economical manner.

All bag chemicals should be stored on pallets to keep them dry and the chemical storage space should be well ventilated to prevent chemicals from absorbing moisture during storage and becoming difficult, if not impossible, to feed satisfactorily in dry feeders. If more than a few bags of chemical per day are to be handled, it may be economical to provide lift trucks for transporting the pallets of bagged chemical from one feeder installation to another.

3. When the chemical is to be stored in bulk, bins must be large enough to hold at least one and one-half times the normal shipping quantity. If the water plant is a great distance from the source of supply, there is a chance of delay in transit and additional storage capacity should be provided, so there will be no danger of the plant running out of chemical between shipments. The usual practice is to provide a minimum of from one and one-half to two carload storage capacity when chemical is purchased in bulk.

Guide No. III
Choose Best Available Location

1. The hydraulics of a chemical feeder installation should be studied very carefully before selection and purchase of equipment and solution lines. Whenever possible, choose a location that will permit the dry chemical to flow entirely by gravity from the storage level to the feeder and dissolving chamber, then by gravity from the solution chamber to the point of application. Such accessories as conveyors, pumps and ejectors should be eliminated if possible.

2. If a location is not available with these ideal conditions, then choose the location that will require as little pump or ejector head as possible. This is particularly important in the feeding of alkaline chemicals when hard water is used in the dissolving chamber. Pumps and ejectors on chemical solution lines always require frequent cleaning and servicing and their use should be avoided whenever possible.

Guide No. IV
Choose Type of Installation

There are four basic types of dry chemical feeder installations:

1. *Small Unit Feeder* (Fig. 1) used when a very low feed rate and small chemical storage capacity is required. The principal parts are: feeder hopper, feeding mechanisms, means for feed rate adjustment, variable speed transmission or equivalent, water supply for mixing jets in dissolving chamber, dissolving chamber sized for adequate detention of the chemical being fed, and platform scales for an accurate check on the performance of the equipment.

2. *Two-floor Installations* (Fig. 2) used for low or high feed rate with bin storage on the second floor. This installation contains the same essential parts as the small unit feeder installation plus an extension hopper for additional storage capacity. This type of installation has the advantage that all chemical is handled in a separate room on the second floor—thus confining to the chemical storage room, dust and dirt incident to handling bagged chemicals. An ideal refinement, highly desirable but not absolutely essential, is a dust collector installed on the extension hopper at the second floor level to eliminate dust in the chemical storage room while loading the hopper.

3. *Mechanical Loading Installation* (Fig. 3) used when the feed rate is high and large hopper capacity is required with bag storage on the first floor. Here again, the essential parts of the chemical feeder installation are included plus an extension hopper, bucket elevator and dust collector. This type of installation is frequently used when new and larger capacity equipment is installed in an existing chemical building. It is also used for new installations with adequate floor space available on one floor for the equipment and chemical storage. (Considerable savings can sometimes

be realized by eleminating the second floor of the chemical building.)

4. *Bulk Storage Bin Installation* (Fig. 4) used for high or low feed rate requirements where chemical is purchased in bulk, usually truckload or carload quantities, and stored in overhead bins. This type of installation is used mostly by large plants where it is economical to purchase chemicals in carload quantities.

These storage bins are usually constructed of concrete or steel and are an integral part of the building. It is considered good practice to make the lower section of the storage bin of steel so that vibrators, plate-type agitators or other agitating devices can be readily installed. A bin installation can be made suitable for practically any type of chemical feeder by fabrication of the steel hopper action to meet installation requirements. Large storage bin installations should include a large rotary bin gate on the outlet of the bin. Minimum size gate 9 x 15 inches, 12 x 12 inches, or preferably 12 x 24 inches. When small bin gates are used on large bins, packing at the bin outlet can be expected.

If the chemical to be stored is of a non-free-flowing type subject to arching and flooding, means for agitation must be provided to insure a flow of material from the storage bin when required. On installations handling a floodable material, the feeder selected should have a Rotolock feeding mechanism incorporated in it to eliminate the danger of flooding through the feeder.

Fig. 6—W&T volumetric feeder A-635
With scales for weight checks.

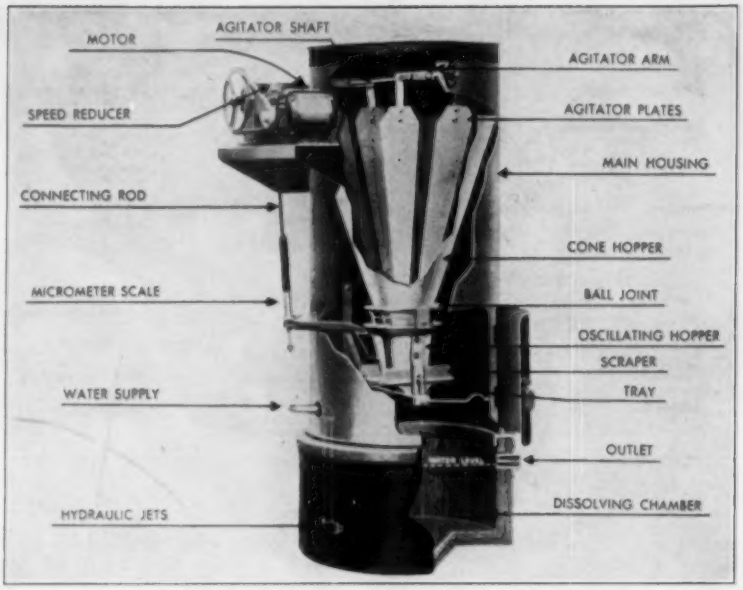


Fig. 5—OMEGA Universal volumetric feeder

Chemical feeder installations under large storage bins should be isolated from the storage bin by means of dust tight flexible connections to prevent damage to the equipment due to expansion and contraction of the large storage bin. The installation shown in Fig. 4 contains all the essential elements of a chemical feeder installation plus the flexible connection, rotary bin gate and bulk storage bin.

Guide No. V—
Choose Type of Feeder

There are two basic types of feeding mechanisms: volumetric and gravimetric.

When variations of three to five per cent plus or minus (by weight) can be tolerated in the feed rate, and when it is not necessary to accurately record or totalize the actual weight of material fed, then volumetric feeders may be used. When more accurate feed rates (within plus or minus one per cent by weight) are desired and when automatic control of feed rate and accurate records of feed rate are required, then gravimetric feeders may be used.

Volumetric Feeders

Volumetric feeders are designed for volume displacement. They do not incorporate scales in their feeding mechanism. If scales are used they are usually platform scales supporting the entire machine and its contents.

Such scales give a check on the performance of the machine, but do not actually control the rate of feed. Any changes in density or feeding characteristics of the chemical being fed will directly affect the actual weight of material fed. Inasmuch as volumetric feeders measure only the volume displaced and not the weight of the material, it is possible for a volumetric feeder to operate mechanically without feeding any material, and there is no means of warning the operator if material is not being fed. For these reasons volumetric feeders usually require more attention from the operators to insure continuous satisfactory operation of the process.

Volumetric feeders can be used in small plants where:

1. Operation rates are relatively constant.
2. Continuous check on performance of the equipment is possible—for example, regular visits by the operator every half-hour or hour, and checks of the material fed by means of platform scales.
3. Considerable retention capacity in the mixing and settling basins is available to average the minor variations in feed rate due to changes in bulk density or feeding characteristics of the chemical.

Typical volumetric feeders include the Omega Universal, Rotolock, and Disc Feeders; Wallace & Tiernan Series A-635, Type NA and Type A-552; Infilco Type D and Type E; and Syntron Vibratory Feeders.

The Omega Universal Feeder (Fig. 5) is readily adaptable for feeding any of the dry chemicals used in

Fig. 7—INFILCO volumetric feeder Type D
With revolving table.

water plants. The feeding mechanism is the large open oscillating throat type. It is accurate volumetrically and is not readily plugged by lumps or trash. Rate of feed is adjustable over a wide range. These machines are manufactured in three sizes with suitable accessories for any of the four types of installations previously described. The principal advantages of using this type of machine are—low first cost, simple operation, and low maintenance service.

The Wallace & Tiernan Volumetric Feeder, Series A-635 (Fig. 6) incorporates a feeding mechanism of the horizontal screw type utilizing a combination of rotary and axial movement through a feed trough discharging chemicals at both ends. The rate of feed is regulated by a cam operated clutch mechanism by means of a control crank. This machine is primarily offered for unit type installations.

The Wallace & Tiernan Type MA Feeder consists of a slow moving feed roll delivering a ribbon of chemical across the feed apron from which it is fed to point of discharge. Changes of feed rate are made by varying the width of the ribbon and by change gears. The Wallace & Tiernan Type A-552 Feeder has the same type of feeding mechanism as the Series A-635 Feeder.

The Infilco Volumetric Feeder, Type D, (Fig. 7) is a disc-type (revolving table) feeder with position of a feed knife on the disc determining the rate of feed. The Type E machine (Fig. 8) is an extrusion type feeder with a feed pan underlying the hopper and moving with a rocking and reciprocal motion. These machines are primarily used for small unit feeder installations.

The Omega Rotolock Feeder (Fig. 9) is a star wheel or pocket drum type of feeder and is recommended for volumetric feeding of floodable materials such as hydrated lime, activated carbon, clay, etc. The feeding mechanism is entirely enclosed and is driven by an infinitely variable speed transmission (100 to 1 range). It is available with electric or pneumatic rate setting devices for use with automatic pH controllers and proportional pacing systems. Accessories for the Rotolock Feeder are available for all four types of installations.

Omega Disc Feeders (Fig. 1) are used for feeding finely ground materials continuously and accurately at very low rates of feed. When the maximum feed rate required is less than 50 pounds per hour, the Disc Type Feeder should be considered. The feeding disc has a scroll type feeding orifice which provides exact volumetric measurement. Delivery of material is continuous even at very low rates, and directly proportional to the number of revolutions of the disc. An infinitely variable speed drive rotates the disc at the desired speed. Machines with a feeding range as low as one to 25 ounces per hour are available. This machine may be equipped with any of several sizes of feeder hoppers including the loading door hopper, all suitable for hand filling from feeder room floor. This machine is generally used for unit feeder installations requiring low feed rates and small chemical storage capacity.

Fig. 8—INFILCO volumetric feeder Type E
With revolving feed pan.

Gravimetric (Weighing) Feeders:

Gravimetric or weighing feeders are machines designed to feed dry chemicals continuously and accurately by weight. They are to be preferred because of their greater feeding accuracy, wide feeding range, and because automatic controls, alarm devices, totalizers and recorders are readily incorporated into the machine. The rate of feed can be pre-set and the feeder will maintain its set rate of feed by weight regardless of changes in bulk density or flowing characteristics of the chemical being fed. They are easily fitted with accessories for accurate automatic proportional pacing from flow meters.

Gravimetric feeders are manufactured in two types: Belt gravimetric and Loss-In-Weight gravimetric feeders. Typical belt type gravimetric feeders include the Omega Chemizer, the Wallace & Tiernan Merchen Feeder, the Jeffrey Waytrol, and the Syntron belt Gravimetric Feeder.

In the Omega Chemizer (Fig. 10) dry chemical enters the feeder at the top, either from an extension hopper or chute, and passes to the feeding mechanism where it is fed to the scale supported weigh belt which delivers the chemical to the outlet of the feeder. The scale controls the feeding mechanism to maintain a precisely uniform weight of chemical on the weigh belt regardless of changes in density.

Adjustment of the feed rate of the Chemizer may be made in two ways; by setting the counterpoise weight on the scale beam to increase or decrease the weight on the weigh belt and allowing the belt to run at a constant speed; or by the preferred method of

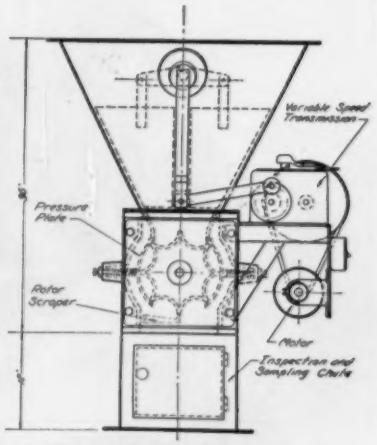


Fig. 9—OMEGA Rotolock feeder

maintaining a constant weight on the belt and varying the belt speed. The scale beam and suspended Omega wedge controls the amplitude of vibrations of the feed tray which delivers chemical to the weigh belt.

When the chemical to be fed is compressible, finely ground and subject to arching and flooding from a storage hopper, a non-flood Rotolock (Fig. 9) is installed above the feed tray in the feeding mechanism.

The Wallace & Tiernon Merchen Feeder (Fig. 11) is of the belt gravimetric type. It incorporates a weigh span between the head and tail rollers of a small conveyor belt, and mercury switches actuated by the scale beam increase or decrease the opening of the feed gate to vary the load on the weigh span. Rate of feed is usually set by adjusting the weight on the scale beam.

The Syntron belt gravimetric feeder (Fig. 12) consists of a short constant speed conveyor belt supported by a small platform scale, and electric vibratory feeding mechanism, and electric or pneumatic controller. Rate of feed is controlled by varying the load on the conveyor belt.

A typical Loss-In-Weight Gravimetric feeder is the Omega Loss-In-Weight feeder (Fig. 13) which, as its name implies, operates on the principle of control of loss-in-weight in the feeder hopper. This machine continuously "weighs out" material from a hopper that is carried on the scales. The rate of feed is determined by the rate that the poise is retracted on the scale beam by a mechanically driven lead screw. Any departure of the beam from exact balance position causes an immediate change in speed of the Rotolock feed mechanism, faster or slower, as required to maintain the scales in balance. The change in speed is affected effortlessly through the Omega wedge control device and the rotatrol mechanism that converts oscillating motion to progressive rotary motion. The Rotolock feeder cannot flood.

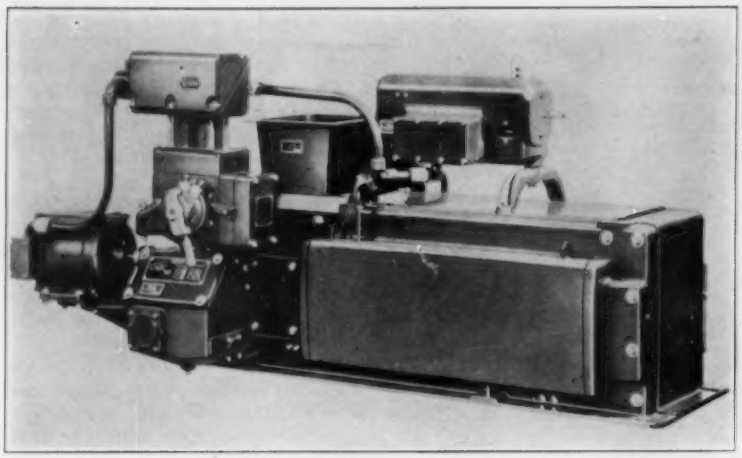


Fig. 11—W&T Merchen belt type gravimetric feeder

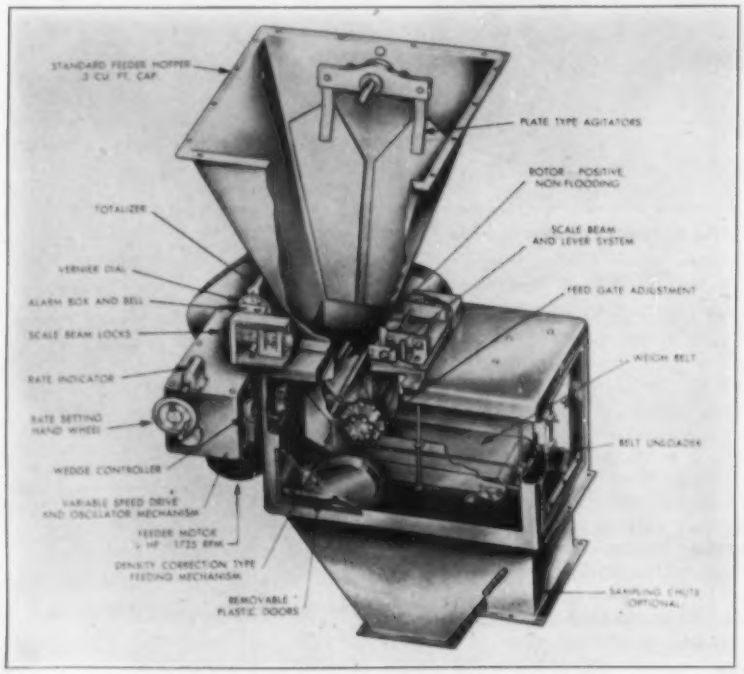


Fig. 10—OMEGA Chemizer belt type gravimetric feeder
With positive non-flood rotor.

Guide No. VI—
Select Accessories For Desired Operations

Practically every chemical feeder installation requires some accessories to satisfactorily accomplish the results required. Such accessories are used at the discretion of the engineer and should be selected on the basis of the actual requirements, making every effort to keep the chemical feeder installation as simple and free from gadgets as possible.

Some of the accessories available are bin level switches, pilot lights, belt shifters, rotary bin gates, remote controls, timers, special electrical starting equipment, control panels, mechanical miners, dust collectors, proportioning weir tanks, dissolvers, and extension hoppers. Accessories such as totalizers, recorders and automatic alarm devices are available on gravimetric feeders only.

There are many other accessories which a chemical feeder manufacturer can usually offer to solve a particular problem.

Guide No. VII—
Furnish Information For Manufacturers

Information that will permit manufacturers to offer satisfactory equipment should include:

1. Chemical and physical properties of the chemical to be fed—name, formula, color, screen analysis, bulk density and any other chemical or physical data available.
2. Type of feeder desired—volumetric or gravimetric, accuracy required (plus or minus 3 to 5 per cent by weight for volumetric feeders, or one per cent by weight for gravimetric feeders); dust removal units, types of controls and accessories desired.

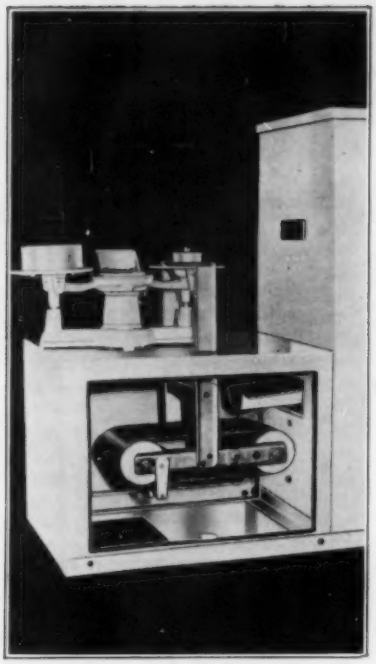


Fig. 12—SYNTRON gravimetric feeder
Belt type.

3. Power available, voltage, phase, cycle and full information on special wiring codes, if any. State if compressed air is available and give full information as to water which will be used including temperature, pressure and hardness if possible. Be sure to mention any special chemical or physical properties of the water to be used.

4. General information—such items as sketches or drawings of space available, indicate bins, hoppers or other equipment existing or to be built which may affect the engineer's recommendations.

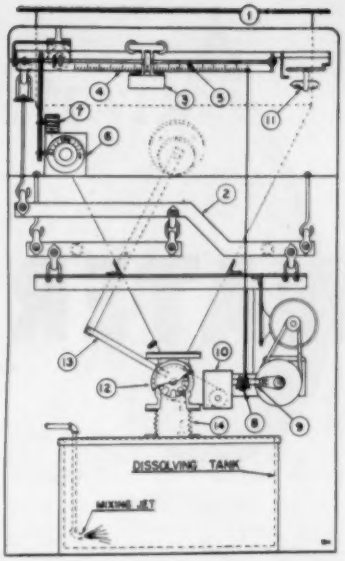
Guide No. VIII—
Evaluate Proposals

Give full consideration to these questions:

1. Does the equipment meet the specifications?

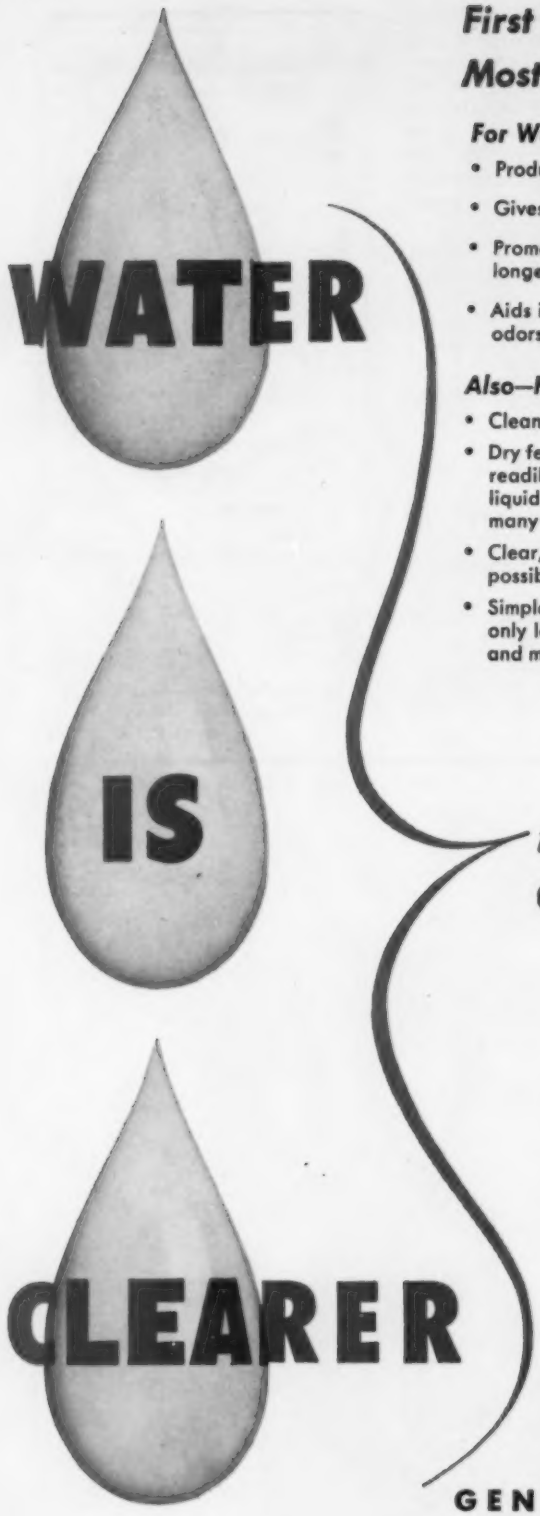
2. Will it provide the performance desired?

3. What are the economics of the installation? Consider economics to be not only the first cost, but also cost of maintenance and service, length of life, and cost of operation.



1. Hopper
2. Scale System
3. Poise
4. Scale Beam
5. Lead Screw
6. Lead Screw Drive
7. Totalizer
8. Wedge
9. Oscillator
10. Rotatrol
11. Alarm Switch
12. Rotolock Feeder
13. Agitator Levers
14. Flexible Connection

Fig. 13—OMEGA gravimetric feeder
Loss-In-Weight type.



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Notes On

COAGULATION AND SEDIMENTATION

COAGULATION is the process of adding a chemical, termed a *coagulant,* and other chemicals under some conditions, to produce an agglomeration (gathering together in clumps or *flocs*) of colloidal and finely divided suspended matter. Two steps are involved, *mixing* or rapid dispersion of the chemicals in the water and *flocculation* or formation of the flocs by slow agitation. In flocculation, small particles come in contact with other particles, and coalesce, agglomerate or grow into large flocs. (The term flocculation is also applied to the slow mixing of liquids bearing suspended matter to produce coalesences of particles and floc formation without the addition of chemicals).

Coagulation is always followed by *sedimentation,* a process whereby suspended matter, including flocs, is allowed to settle out of a liquid under conditions which favor the action. These conditions are such that the water moves very slowly through a settling basin with little or no agitation. The two processes of coagulation and sedimentation, together, are often termed *clarification.*

Coagulants

There are two principal groups of coagulants: the salts of aluminum and of iron. The most common coagulant, filter alum, is a slightly dehydrated crystaline compound of aluminum sulfate. It has an approximate composition of $Al(SO_4)_3 \cdot 15H_2O$. AWWA specifications call for a content of water soluble Al_2O_3 of 17 per cent, a maximum iron content of 0.75 per cent Fe_2O_3 and a limit of 0.5 per cent of insolubles for purified alum (10 per cent for unpurified alum). The chemical is shipped in 100 lb bags or cartons or in bulk and it may be powdered, granular or lump.

Another aluminum compound, which may be used, is sodium aluminate; essentially aluminum dissolved in caustic soda (NaOH) to produce $Na_2Al_2O_4$. It may be shipped as a concentrated solution in steel drums or as a dry powder in drums or paper bags. It is used principally in boiler water treatment.

Liquid alum, sometimes called alum syrup, may be made on the premises from bauxite and sulfuric acid or shipped from a manufacturer, if the distance is not too great. It may contain from 5.8 to 8.3 per cent Al_2O_3.

Iron compounds which are used as coagulants include ferric sulfate $Fe_2(SO_4)_3$; ferric chloride $FeCl_3$; ferrous sulfate $FeSO_4$; and chlorinated copperas, a mixture of ferric sulfate and ferric chloride produced when ferrous sulfate (copperas) solution is treated with chlorine. Ferrous sulfate cannot be used alone as a coagulant; lime must be added to the water to be coagulated.

In addition to coagulant chemicals, there are certain *coagulant aids,* which improve coagulation and floc formation when added to a water being coagulated. Most important is activated silica, a colloid produced by careful treatment of sodium silicate solution with an activating agent such as alum, chlorine, sulfate acid, etc. Activated silica can be used alone as a coagulant under some conditions. Other coagulant aids include acid or alkalies for pH adjustments, artificial turbidity produced by clays or activated carbon.

Chemical Reactions

Simply stated, when a coagulant is added to water, it reacts with alkalinity (either naturally occurring or added by lime) to form a gelatinous flocculant precipitate, a hydrous oxide of the metal in the coagulant. Actually, it has been shown that the reactions which occur in the coagulation process are extremely complex. There is a direct union of the metal ions with impurities, the formation of complex hydrous oxides on which are adsorbed impurities, the formation of negative ions such as basic carbonates and sulfate ions and the destabilization of colloids by colloids and ions of opposite electric change. It is impossible to express the reaction by an exact chemical equation because the reaction depends on the pH, alkalinity, concentration of impurities and other chemical ions in the water.

For practical purposes, however, simple equations are written to show the approximate reactions which take place. These reactions for alum and ferric sulfate, with natural alkalinity are:

$$Al_2(SO_4)_3 \cdot XH_2O + 3\ Ca(HCO_3)_2 \rightarrow 3CaSO_4 + 2Al(OH)_3 + 6CO_2 + XH_2O$$

$$Fe_2(SO_4)_3 \cdot XH_2O + 3\ Ca(HCO_3)_2 \rightarrow 3CaSO_4 + 2Fe(OH)_3 + 6CO_2 + H_2O$$

Reactions for alum and ferrous sulfate (copperas) with added lime are:

$$Al_2(SO_4)_3 \cdot XH_2O + 3Ca(OH)_2 \rightarrow 3CaSO_4 + 2Al(OH)_3 + XH_2O$$

$$FeSO_4 \cdot XH_2O + 2Ca(OH)_2 \rightarrow 2\ Ca\ CO_3 + Fe(OH)_2 + 2H_2O + XH_2O$$

Ferrous hydroxide, however, is soluble to approximately 7 ppm. It is oxidized to insoluble ferric hydroxide at a high pH value, according to the equation:

$$4Fe(OH)_2 + 2H_2O + O_2 \rightarrow 4Fe(OH)_3$$

Factors in Coagulation

According to the AWWA "Manual of Water Quality and Treatment" there are several factors which affect coagulation of turbid and colored waters. These include kind and quantity of coagulant used, characteristics of water (color turbidity, dissolved chemicals, pH and alkalinity); temperature of the water, mixing and flocculation time, violence of agitation, and the presence of nuclei.

Of these several factors only the kind and quantity of coagulant can be controlled easily. The mixing and flocculation times are set by the design and are not subject to control of the operator and other factors are outside the operators sphere of control.

Choice of Coagulant: The most widely used coagulant is filter alum, although iron salts are employed in many plants. Filter alum has certain advantages; it does not cause red-brown staining of flocs, walls or equipment, it is not as corrosive as solutions of ferric iron salts, and the trivalent aluminum ion is not reduced to the more soluble bivalent ion in the presence of organic matter. On the other hand, ferric iron floc is denser than alum floc and precipitates more completely over a wider range than does alum. Ferrous sulfate must be used with lime which is a disadvantage. The ultimate choice of coagulants, depends principally on local conditions and cost of the coagulant.

Amount of Coagulant: The amount of coagulant needed must be determined for each water supply and for each change in condition in that supply. There is no definite relation between amount of coagulant and the amount of turbidity in the water. The exact dosage will depend on temperature and other characteristics. It may vary from 2 to 100 ppm. To determine the best or optimum dosage, an operator should use the jar test. In this technique, a series of jars is set up, each jar containing about 1½ liters of water. Coagulant is added to all jars, with each jar receiving a greater dosage than the previous one in the series. The liquid in the jars is then stirred for 15 or 20 minutes or a period of time equal to the flocculation time in the plant. At the end of the stirring period, observations are made to determine which dosage produces the best floc and the best settling. That dosage is used in plant operation.

Characteristics of Water: Cold water generally requires a longer mixing and flocculation time and frequently will require more coagulant to produce the desired floc. Finely divided and colloidal turbidity requires more coagulant to produce a good floc than does turbidity caused by coarse particles. Highly colored waters usually require higher coagulant dosages.

For good coagulation, there must be sufficient natural alkalinity to insure that the floc will precipitate or lime must be added. The optimum pH zone where coagulation is most complete differs for different coagulants and depends somewhat on the presence of other ions. Aluminum sulfate has a flocculation range of pH from 8 to 9 in the alkaline range and 4.5 to 5.5 in the acid range for soft colored water, but the upper range is extended to 4.5 to 8.0 when the concentrations of sulfate ions is from 50 to 100 ppm. Ferric iron salts may be coagulated over a pH range above 4.0.

Mixing and Flocculation Time: Usually mixing time is a few minutes at most. The purpose of rapid mixing is to disperse the coagulant completely throughout the water being treated. During this time, the positively charged metal ion of the coagulant attracts and neutralizes negatively charged colloidal impurities, positively charged colloidal flocs are produced from the reaction of coagulant and alkalinity, and impurities are adsorbed on the flocs.

Following these reactions in the mixing period, a period of flocculation, for 20 to 60 minutes, is necessary to cause these minute flocs to grow into large clumps that will settle readily. The greater the dosage rate of coagulant, the shorter the time required for flocculation, but the relation is not direct. The object of good coagulation practice is to produce the best possible floc in the time available with a minimum of chemical. This is the reason for making coagulation jar tests.

Violence of agitation: Mixing should be rapid and voilent to insure complete dispersal of the coagulant. In flocculation, however the extent of agitation must be such that it causes flocs to form, not to break up. Floc growth results from collision of small floc particles and from adhesion of these particles to each other. Collision is brought about by the slow gentle mixing produced by moving paddles or by passing the water through a maze of baffles. If this agitation is too rapid the flocs will cease to grow before reaching the desired size or the flocs will break up. Mechanical flocculators should *not* rotate at a blade-tip speed greater than 1.3 ft per sec, preferably at 1 ft per sec.

Nuclei: Suspended particles of turbidity act as nuclei on which the floc forms; hence turbid water is easier to coagulate than clear water. There are several means by which nuclei can be supplied artificially, including the use of activated silica, the addition of clay or activated carbon and the return of previously formed floc. The latter method is accomplished by flocculators which carefully pick up the first floc to settle and resuspend it. A similar effect is accomplished in up-flow clarifiers where incoming dosed water passes through a bed of previously formed and settled floc.

Chemical Feeding

As pointed out therefore, chemicals may be purchased as dry powder, granuales or lumps or in liquid solution. Alum, sodium aluminate: ferric, sulfate may be obtained in dry form. Alum, sodium aluminate and ferric chloride may be obtained in concentrated solution. Chlorinated copperas is made as a solution on the premises. Chemical feeders are used to measure and add the coagulant at the desired dosage rate. (See the section on Chemical Handling and Feeding.)

Sedimentation

Settling tanks or sedimentation basins always follow coagulation for the purpose of allowing the floc, sediment and impurities to settle out before the water reaches the filters. Most of the impurities, even including a large part of the bacteria present, are removed during sedimentation. The better the sedimentation, the less work to be done by the filters.

Design features of sedimentation basins affect many phases of operation. These design features are important; velocity of flow, detention or flow through time, sludge storage volume and method of sludge removal, inlet and outlet arrangements, etc.

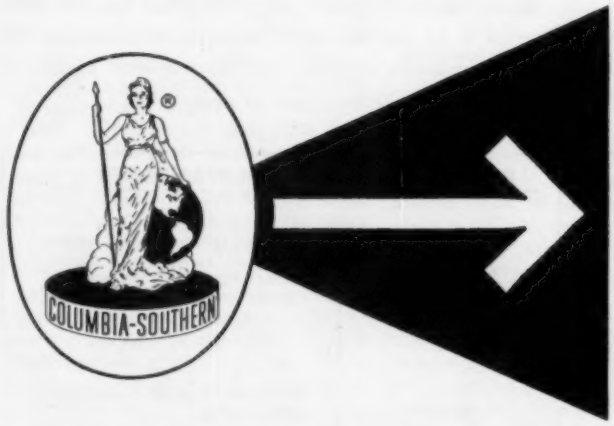
Other factors which affect the operation and efficiency of sedimentation tank include size, specific gravity and concentration of particles, biological activities, electrical effects, etc. Settling periods of 1 to 6 hours are used. The rate of flow through a basin (flowing-through period) should not be less than 30 per cent of the detention time (i.e. time required to fill a basin at the given rate of flow).

Continuous removal of sludge from sedimentation basins makes possible the use of smaller tanks, and better results. Intermittent sludge removal requires that the operator set cleaning schedules which will maintain operation at efficiencies above the minimum allowable, and will prevent tastes and odors from decomposing sludge. Usually, this cleaning operation should be performed whenever the depth of the sludge reaches three or four feet.

Sedimentation, when practiced without coagulation, is termed "plain sedimentation" and is used in two situations, either as the sole treatment prior to filtration or as pretreatment before coagulation. Where plain sedimentation is used in place of coagulation and sedimentation, the reservoir used for the purpose should have a capacity of several days to several weeks. If the reservoirs are large enough to permit storage for weeks or months, filtration may not be necssary but disinfection should be practiced.

When sedimentation is used as a pretreatment before coagulation and sedimentation, the purpose is to reduce the load on the coagulation process and amount of coagulant required. Furthermore, this pretreatment is used on extremely turbid waters, containing sediment that will settle rapidly without the aid of coagulating chemicals. Presedimentation basins should have a capacity equal to 6 to 24 hours detention period at average flow.

Columbia-Southern chemicals for water and sewage treatment



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Chlorine in dry, white, tablet form. Consists of Calcium Hypochlorite containing a minimum of 70% available chlorine.

Especially valuable in swimming pools because the tablets are slow dissolving and provide a continuous supply of available chlorine throughout an 18-hour cycle. Pittabs are excellent for uses in water and sewage works where the advantages of slow dissolving chlorine tablets are of value.

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For further information on any of these products, please contact the Pittsburgh office or any of the branches.

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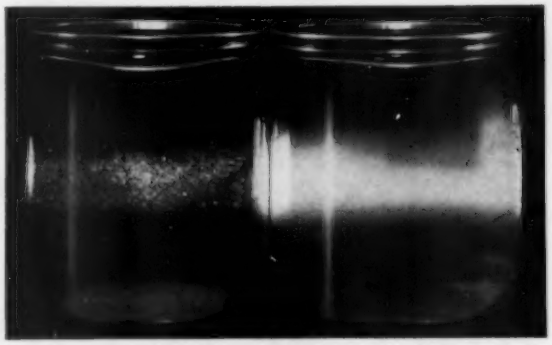
Activated silica sol is made with N Silicate of Soda (41° Baume) and a reactant chemical at the plant where it is used. PQ's N-Sol Processes using reactants as noted below are licensed without royalty. (The use of sulphuric acid is covered by U. S. Pat. 2,217,466, J. R. Baylis, City of Chicago.)



Jar tests showing increased floc size with activated silica plus alum on the left as compared to alum alone on the right.

PQ Assistance

Samples of N Silicate of Soda and directions for making jar tests are available on request. PQ engineers are glad to share our experience with activated silica sol as an aid in water treating problems. Ask for our #52 series to be sent to you in a convenient reference file folder. Silicates are also used for corrosion control in water systems. Request bulletin series #37.

COAGULATION	PROCESS	REACTANTS	ADVANTAGES
Raw Water Improves quality Lengthens filter runs Removes high color Reduces turbidity Removes manganese Removes magnesium Removes calcium	N-SOL-A (U. S. Pat. 2,444,774)	ammonium sulphate	Ease of preparation, either batch or continuous. Chloramines formed in waters previously treated with chlorine.
Waste Water Recovers reusable solids Prevents stream pollution Clears effluent	N-SOL-B (U. S. Pat. 2,310,009)	alum	Reactant readily available, inexpensive.
In Such Industries as: Paper Petroleum Metal Finishing Plating Food Textile	N-SOL-C (U. S. Pat. 2,567,285)	chlorine	Reactant usually available where sterilization is normal practice.
Also Radio Active Waters	N-SOL-D	sodium bicarbonate	Used where an alkaline salt is desired. For boiler feed water where ammonia is not desired.

Preparing and Using Activated Silica

By CHARLES A. BLACK
Pres., Black Labs., Inc., Gainesville, Fla.

ACTIVATED silica, although its application to water treatment is relatively new, actually has a long history. More than 150 years ago, Pott reported the preparation of a "semi-solution" of silica, but Graham is usually credited with the discovery of silica sol.

The first successful efforts to use silica sols on a large scale in water treatment took place in 1936. The work was done independently and concurrently by J. R. Baylis at Chicago and by Graf and Schworm at St. Louis. Baylis showed that the addition of sulfuric acid to a dilute solution of sodium silicate, with proper aging, could improve the alum coagulation of Lake Michigan water appreciably. Graf and Schworm demonstrated, in both laboratory experiments and plant scale trials, that solutions of alum and sodium silicate of approximately equal concentrations could be used as an effective coagulant aid. It is surprising to note that, as early as 1884, Graham was so close to the views now considered modern. Graham has been generally credited with introducing the terms sol, gel, and peptization.

Definition of Terms

Because activated silica, although in limited use for a great many years, has not as yet been widely accepted throughout the country as a conventional coagulant or coagulant aid, some of the terms employed in this paper may not be familiar. Consequently, it has been deemed advisable to include the following definitions applicable to the theory of activated silica:

Activated silica. This term designates a negatively charged colloidal particle formed by the reaction of a dilute sodium silicate solution with a dilute solution of an acidic material or other activant.

Sol. This is a general term applied to colloidal dispersions as distinguished from true solutions.

Gel. A silica gel is a heavily hydrated, interlaced, fibrillar or brush heap structure of very large polysilicic acid molecules, with the spaces filled with water or dilute silicate solution.

Gel induction time. The time interval between the addition of the activant to the sodium silicate solution and the first determinable gel formation is the "gel induction time" (sometimes called "gel time").

Micelle. This term, taken from the French, has been construed to indicate an internal-phase particle that possesses a double layer of charges of opposite sign adjacent to the surface. As applied to activated silica, it usually refers to a particle size varying between 0.1 and 1.0 mμ.

Mole ratio. As applied to activated silica, this term refers to the ratio of the number of moles of activant to the number of moles of sodium oxide in the silicate.

Percentage neutralization. Taking a 1:1 mole ratio of activant to sodium oxide content as unity, or 100 per cent, this term expresses as a percentage the ratio of equivalents of activant to equivalents of sodium oxide content added in the neutralization process.

Parts per million activated silica ($^{-}SiO_2^{-}$). This term represents the parts per million available $^{-}SiO_2^{-}$ micelles present. These micelles have a negative charge and should not be confused with SiO_2 as normally found in water supplies.

Methods of Activation

Activated silica sol, prepared by the partial or total reaction of the sodium oxide content in sodium silicate, has often been applied successfully as a coagulant aid. The process involves the reaction of a suitable grade of sodium silicate, such as one having a ratio of 1 part Na_2O to 3.2 parts SiO_2. A typical analysis is: Na_2O, 8.9 per cent; SiO_2, 28.7 per cent; and H_2O, 62.4 per cent. The activation of sodium silicate with strong acids follows a pH curve similar to that for the reaction of a strong acid and strong base.

Probably the first activated silica sol successfully used as a coagulant aid in the treatment of raw water was developed by Baylis[1], working in Chicago on Lake Michigan water. He found that, when the alkalinity of sodium silicate was partially neutralized by sulfuric acid, it acted as a coagulant aid for this water. The Baylis process involved the addition of a diluted sodium silicate solution to a level of 1.5 per cent SiO_2 and the addition of sulfuric acid sufficient to neutralize approximately 85 per cent of the alkalinity. This solution was aged for 2 hr and then diluted to a level of 0.6 per cent SiO_2, producing a very efficient coagulant aid.

The Graf-Schworm process[2] involves the addition of 1 per cent alum solution to a 1 per cent silicate solution in a ratio of 4 parts of alum to 1 part of silicate. This mixture is then used immediately as a coagulant aid.

A method of activation developed by Hay[3] involved the use of ammonium salts. This method differed from both the Baylis and Graf-Schworm processes in that it did not involve alkalinity neutralizaton and the pH of the final silica sol was much higher than in either of the other methods. Hay also suggested the use of carbon dioxide, sulfur dioxide, sulfur trioxide, chlorine, and acid salts as activating agents, as well as the concept of continuous activation. The Hay process for activating silica is commonly called N-Sol A. The usual method of producing this sol is to mix diluted silicate and ammonium sulfate solutions in equimolar proportions, to age this mixture at a concentration of 2 per cent SiO_2 for 1 hr. and then to dilute it below 1.3 per cent for storage to prevent gel formation. This sol has less tendency to gel and can be safely stored and used at approximately twice the safe storage concentration of the Baylis sol.

The Baker-Dedrick sol[4], commonly called N-Sol B, is produced by adding dilute solutions of sodium silicate to dilute solutions of a metal salt capable of forming an insoluble silicate. These solutions are mixed in equimolar proportions, aged, and added to the water treatment system or diluted to prevent gel formation.

Many other activants have been used to form activated silica sols, but the methods previously mentioned are the most important insofar as general acceptance and basic work are concerned. Silica sols made by the hydrolysis of silicon tetrachloride have only a slight effect on coagulation. Those prepared by the passage of a diluted soluble silicate through an ion-exchange resin have little, if any, coagulant activity.

Theory

The internal-phase fibers of a silicic acid gel are regarded by Hurd and Miller[5] as consisting of condensed silicic acid molecules that form long,

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branched chains profusely entangled. This condensation is produced by the splitting off of the water, starting at first by a reaction between simple molecules and continuing between the larger molecules thus formed until a network develops. The vast surface created by such a brush heap structure of combined silicic acid molecules can account for the adsorption of the water molecules and for their being held in a more or less rigid condition. According to Hurd and Miller, any condition that tends to alter the rate of reaction accordingly affects the rate of the setting of the gel. During the aging period, the low-molecular-weight polymer of silicic acid formed by the neutralization of the silicate alkalinity by acidic material increases in size. If the aging process is not stopped by dilution, addition of alkali, or other means, the mixture gels. By controlling the aging time, the size of the silica micelle can be varied over a wide range. During aging, the more soluble silica changes to a colloidal form that does not react with ammonium molybdate in the usual analytical test for silica.

Assuming that the gelatin is due to a condensation reaction of this type, fastest gelling should occur near the pH of least ionization, where there is a minimum of repulsion forces between similarly charged silicic acids or hydroxides or an equal number of positively or negatively charged species containing silicon hydroxides. The occurrence of such a maximum rate of gelation at an initial pH of approximately 7 is evidence that the silicic acids are much stronger than is ordinarily supposed. The increase in pH during aging and gelation indicates that the polysilicic acids forming are weaker and are more extensively hydrolyzed. Published data[4] clearly shows that the gelling power of ammonium salts is not due entirely to acid formed by hydrolysis, as they form gels at pH values only slightly less alkaline than the sodium silicates themselves. Systems of silicates with acids do not form gels at these pH values. The sodium aluminate-silicate mixtures have higher pH values than silicate solutions alone. The ability of ammonium salts to gel sodium silicates is, therefore, probably due to the formation of slightly ionized, heavily hydrated, insoluble gelatinous salts.

The sodium silicoaluminate gels formed when sodium silicates and aluminates are mixed contain sodium ions that are not removable by extensive washing with water. These sodium ions are replaceable with other cations like calcium and magnesium. Such products, usually termed artificial zeolites, are used extensively in water treatment. Because aluminum or aluminate ions, as well as the silicates, can be regarded as polyfunctional, the formation of a silica alumina gel probably involves copolymerization reaction.

Thus, it can be seen that there are at least four distinct methods of forming activated silica sols and silica gels: (1) alkalinity neutralization with acids or acid salts; (2) the use of ammonium sulfate to form slightly ionized, heavily hydrated gelatinous salts; (3) the use of sodium aluminate to form silico-aluminate sols; and (4) the addition of dilute solutions of a metal salt to sodium silicate to form insoluble salts.

In general, the rate of gelation of mixtures of 3.3-ratio sodium silicate with the various gelling agents increases in the following order: ammonium sulfate, sulfuric acid, hydrochloric acid, and sodium aluminate. Under certain conditions this order does not hold, however. The mole ratio of the gelling reagent to the alkali of the silicate does not affect the gel time as much with the aluminate and ammonium salts as it does with the acids.

The actual point of gel formation is usually determined by the loss of uniform fluid flow, the appearance of breakage planes when the mixture is tilted, and the adherence of solid gel to the glass wall of the container. The gel induction time obtained in this manner is reproducible within 2 per cent and usually corresponds fairly closely to the "time of set" determined by the "tilted-rod" method extensively used by Hurd and collaborators.

It has been found[6] that, for best results, the aging period for activated silica sols should range between 10 and 50 per cent of the actual time necessary for gel formation. Optimum results are usually obtained when the aging period is approximately 25 per cent of the gel induction time.

Carbon Dioxide and Chlorine Activation

The three methods of silica activation probably most widely used at present employ sulfuric acid, alum, or ammonium sulfate. At least two additional methods, developed in recent years, have shown considerable promise, however. One of these involves the neutralization of the alkalinity by the use of carbon dioxide. This method is of special interest where carbon dioxide is available from the burning of lime sludge in softening operations or as a constituent of burner gases. This activation process, utilizing gases from the exhaust of diesel engines containing 4-5 per cent carbon dioxide gas, is now being employed at Miami, Fla.[7] Activated silica is prepared in batch quantities, and approximately 30 mgd of water is being treated with approximately 2 ppm "SiO_2".

Another process coming into wide favor at present utilizes gaseous chlorine for activation. This method of activation has many advantages. The hypochlorite produced in the reaction contains, in effect, the same oxidizing power as the original chlorine. Hence, none of the chlorine applied is lost, and it is available for disinfection and oxidation of organic materials. Thus, the actual cost of chlorine as an activator is nothing, as it will replace an equivalent amount already used in the filter plant. The relatively low solubility of chlorine in water complicated the development of a continuous process for the production of this sol, but this difficulty has been overcome by at least two major chemical-feeder manufacturers. One of these feeders utilizes a high percentage of activation, a relatively high "SiO_2" content of the aging mixture, and a very low aging time. The solution to be used is prepared continuously and employed immediately after preparation.

Benefits of Activated Silica

The application of activated silica to water treatment has brought numerous benefits never before obtained with a coagulent aid. Baylis' study[1] showed that, in Lake Michigan and synthetic waters, the sol decreased the time required to form a floc; increased its size, toughness, and density; permitted more rapid settling; produced a clearer settled and filtered water; and lengthened filter runs. The sol made it possible to use higher flow rates and coarser filter media and produced good water over a wider pH range. Magnesium could be removed at a lower pH by using the sol. If considerable magnesium was present, it could be coagulated by lime and silica alone.

The first successful plant scale use of activated silica sol employing ammonium sulfate was made in 1943 by Black[8] in a Florida plant. The addition of 4 ppm silica as "SiO_2" prior to feeding 85 ppm of lime and 8.5 ppm alum produced a larger, tougher, heavier floc that settled faster and resulted in increased color removal

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$$Cl_2 + H_2O - HCl + HClO$$
$$SO_2 + H_2O - H_2SO_3$$
$$H_2SO_3 + HClO - H_2SO_4 + HCl$$

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and clearer water. In this plant, the addition of 4 ppm silica replaced a dosage of 70 ppm alum as a coagulant with a very substantial financial saving. At approximately the same time Black also initiated the application of activated silica to a softening plant, using sulfuric acid as the activant. Since then activated silica has become a standard coagulant for lime softening in Florida, and, to some extent, has replaced alum. It is also used as a coagulant aid in the treatment of surface waters with alum. It gives a tougher, heavier, and faster settling floc than alum alone.

The benefits observed when activated silica has been used in raw-water coagulation are many, although all are not obtained in every instance. Often a saving in the cost of chemical treatment results from the reduction in the amount of alum or iron salts needed for good coagulation. Sometimes the saving stems from increasing the capacity of the equipment by creating a heavier floc, thus making the existing equipment serve at higher capacities and either postponing the necessity for expanding the plant or reducing the initial cost of new installations. Almost always activated silica in the proper proportion increases the speed of formation and the size, density, and strength of the floc.

It should not be assumed that, because silica is present in a raw water to the extent of 10-20 ppm, activated silica will not be beneficial. The natural and activated forms of silica differ, or at least produce different effects. Usually, adding activated silica to the raw water along with the other coagulants will actually decrease the silica content of the finished water, because more and better coagulation is obtained.

Activated silica has been demonstrated to be a very economical method of treatment. A recent installation in an eastern steel mill showed almost a 50 per cent reduction in water treating cost when activated silica sol treatment was started. Hazlip[8] stated that, at Houma, La., the use of activated silica and reductions in the amount of other chemicals fed decreased the cost from $41.41 to $20.72 per million gallons of water treated. The cost of silica sol application is estimated at 35-50 cents per part per million "SiO_2" for each million gallons of water treated.

Black[3] found activated silica highly effective when used in conjunction with the lime softening of Florida well waters. The process usually consists of softening with excess lime and using approximately 8.5 ppm alum as the coagulant. In some plants, the silica is substituted for all of the alum; in others, the addition of alum with the silica has been found desirable. With the silica treatment the floc particles are large and "leathery." Turbidities of settled waters are reduced greatly and the filter runs are lengthened. Black states that, although activated silica used in conjunction with another coagulant should properly be called a coagulant aid, the time has come to recognize that it may, and often does, act as a coagulant in the truest sense of the word.

Plant Applications

It is important to learn the optimum proportions of activated silica and other coagulants and the proper order of addition. These factors should be studied by means of jar tests, which, if carefully conducted, give a good indication of results to be expected in plant practice. The amount of activated silica usually required varies from 2 to 15 ppm. Excessive amounts of silica destroy the effectiveness of the alum, and no coagulation is obtained. The point of application of the silica is often a critical factor. In combination with alum, negative results are sometimes obtained when the silica is added ahead of the alum; whereas, when the silica is added immediately after the formation of a pinpoint floc, a large, heavy alum floc results. Very often, however, it is found that the silica should be added to the raw water ahead of the other chemicals. The optimum procedure must be determined by jar tests and plant trials.

The effect of temperature on the results obtained with activated silica was investigated by Spencer, Middleton, and Merrill[7]. It was found that activated silica appreciably lessened the time necessary for floc formation at low temperatures. The use of activated silica at low temperatures also greatly decreased the problem of after-precipitation of alum.

Effect on Filter Runs

It has been reported by several persons that activated silica has decreased filter runs. Upon investigation by the individuals concerned, it was found that a sticky, gelatinous film had formed on the top of the filter, thus plugging it. Several explanations for this phenomenon have been found. If only part of the sodium alkalinity is neutralized, the floc formed may be sticky and could, under unfavorable circumstances, cause filter plugging. No difficulty of this type is encountered with ammonium alkalinity. Filter plugging occurring when Baylis sol of 85 per cent neutralization was used disappeared when the silicate was 95 per cent neutralized with sulfuric acid or 100 per cent activated with ammonium sulfate. A change in the alum-silica ratio or in the relative points of application of alum and silica may also eliminate filter plugging.

In one installation, it was found that the proportion of mud and floc indicated that backwash was decidedly inadequate. Surface wash units were installed in the filter beds. With the efficient surface wash, a negligible amount of dirt remained after backwashing, and filter plugging was entirely eliminated. Because a certain quantity of floc is carried to the average filter bed from the sedimentation basin, the application of silica is warranted only if it is known that an efficient backwash is possible. If the silica-alum floc, which is dense and slightly sticky, cannot be washed properly from the bed, it accumulates in serious proportions, increasing the frequency of backwash to a point at which operation becomes very difficult. This problem is especially likely to arise if the filter beds are dirty before the application of silica.

Conclusions

Activated silica sols are truly a welcome addition to the family of chemicals available for water treatment. When properly applied in correct dosages activated silica will almost always improve the coagulation and chemical quality of the water treated. Activated silica, like all other chemicals used in water treatment, must, however, be properly applied or its beneficial effects cannot be realized. It is the opinion of the author that future applications of activated silica in this country will be numerous and that the trend will be toward continuous activation with carbon dioxide and chlorine.

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Discussion

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The author has outlined the uses and characteristics of activated silica and has shown that many reactants can be employed. He has indicated that heretofore activated silica has been prepared largely by the batch method and has pointed out that continuous methods are desirable but not as yet widely accepted. It is the purpose of this discussion to describe how chlorine is used in the continuous activation of silica.

For several years this method has been employed on a batch basis in paper making and in the clarification of domestic water, with makeshift activation units. Klinger[1] and others who have investigated the applicability of chlorine-activated silica have found it to compare very favorably with earlier methods. Chlorine-activated silica is especially attractive because all the chlorine used for activation is available in full strength to perform the normal functions of chlorine. This means that every pound of chlorine used in activation can be chlorine dosage. In plants where prechlorination has not been practiced, this silica activation process will yield all the benefits of prechlorination in addition to its primary function of activation, and, if the chlorine demand of the raw water is not too high, there will be a good chance that postchlorination can be reduced to some degree.

The activation of silica with chlorine differs from other methods in several respects: the aging time has been greatly shortened, the silicate is pumped full strength, and the process is continuous. The procedure is relatively simple because it entails the control of only three ingredients—chlorine, water, and sodium silicate. As in other methods, the sodium silicate is diluted and the alkali is partially or wholly neutralized. This neutralized solution is then aged, further diluted, and fed to the point of use.

Description of Equipment

In equipment developed for this process, the dilution water and chlorine are conducted into a reaction chamber where the sodium silicate is diluted to the proper point and the chlorine neutralizes the alkali to the proper degree. Aging takes place in the same chamber. The finished product is removed by an ejector system, which, in some ways, is the heart of the process. In addition to removing and transporting the finished product to the point of use, the ejector also creates the vacuum needed to meter the flow of chlorine, pulls in the air used in mixing, and provides the necessary final dilution water for stabilizing the finished solution.

The finished solution contains, in addition to silica micelles ($^-SiO_2^-$), all of the chlorine used in the neutralization of the alkali. The process may be expressed as an equation:

$$Na_2O{\cdot}SiO_2 + HOCl + HCl \rightarrow {}^-SiO_2^- + NaOCl + NaCl + H_2O.$$

It will be noted that the $^-SiO_2^-$ does not enter into reaction with chlorine but is simply released from captivity, as it were. The oxidizing power of the chlorine used remains, in the form of sodium hypochlorite (NaOCl). This provides the basis for the previous statement that all the chlorine used is available for the normal functions of that chemical. The pH of the solution delivered to the point of application ranges from approximately 7.0 to 8.5.

Operation is simple. Chlorine, water, and sodium silicate feeds are set in accordance with a chart showing the amount of each required to produce the proper grade of activated silica. Chlorine feed is calibrated in pounds per 24 hours, water in gallons per minute, and sodium silicate in gallons per day.

This system works very close to the minimum sol life of the activated silica. When $^-SiO_2^-$ is released, the time required for it to form a gel will depend upon the initial dilution and the degree of activation. Thus, in the activation of silica, the sol life or gel time is controlled. In batch treatment, the sol is usually aged several hours and then diluted to a working strength of approximately 0.5 per cent. In the system under discussion, the sol life is relatively short—minutes instead of hours—and can be controlled. The sol is made and used within a matter of minutes, thereby decreasing the need for holding tanks and greatly simplifying the operation.

Good results in the preparation of activated silica depend to a considerable degree on proper initial mixing. The air used for this purpose in the continuous chlorine method is drawn into the reaction chamber by the vacuum created by the ejector. Entering at the bottom of the chamber, the air bubbles upward against the downward flow of silicate and water. The appearance of a bluish color or haze is evidence of properly activated silica.

Difficulties due to uncontrolled gelation at unpredictable times have been completely eliminated in this system. The only place where any gel can accumulate is the reaction chamber, from which it can be removed easily by loosening two wing nuts, thus releasing the entire jar. A rub of the hand on the inside removes all gel, and, after replacement of the jar, the equipment is again ready to run. The whole operation seldom requires more than a few minutes.

The ejector which removes the activated silica from the reaction jar and provides a vacuum for the operation of the whole system is of such size that the water used produces a final dilution of approximately 0.5 per cent. This final dilution inhibits further micelle growths, so that the product then can be transported any reasonable distance without danger of gel formation. This is equivalent to the final dilution in the batch method that constitutes the working solution.

This system has passed through the field experimental stage. Units are now in operation on a great variety of waters and purification systems. Where the use of activated silica is justified, the chlorine activation process is proving as efficacious as other methods of activation, and the unit has demonstrated its reliability.

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Mechanism of Water Pipe Corrosion

by ROLF ELIASSON and JAMES C. LAMB III

Prof. of San. Eng., Inst. of Technology, and San. Engr., Amer. Cyanamid, respectively

IRON occurs in nature in the form of an oxide or hydroxide, and the metal is produced through reduction of the ore. Corrosion may be considered as the reverse of this process, as iron is unstable in a corrosive environment and tends to revert to the more stable oxides.

The tendency of a metal to go into solution, or to corrode, is indicated by its electrode potential in that solution. In order to provide a standard basis for comparing the solution tendencies of the various metals, a metal ion "activity" of 1 mole per 1,000 g of water and a temperature of 25°C have been assumed in the preparation of the electromotive force series. In the abbreviated emf series presented in Table 1, the potential of hydrogen is taken as zero and all other potentials are referred to this value[1,2]. The metals are listed in order of decreasing solution tendency (increasing nobility of potential). The potential, E, of a metal under other conditions of temperature and metal ion activity may be found through the use of the Nernst equation:

$$E = E_0 - \frac{RT}{nF} \log_e (M^{++})$$

in which M^{++} is the metal ion activity in solution (gram-moles of metal per 1,000 g of water, multiplied by the activity coefficient); R is the gas constant, in joules; T is the absolute temperature (Kelvin); n is the number of electrons participating in the reaction; E_0 is the potential, in volts, of the metal at 25°C with unit metal ion activity; and F equals 1 faraday equals 96,500 coulombs per equivalent.

Table 1

ELECTROMOTIVE FORCE SERIES*

Electrode Reaction	Standard Electrode Potential (E_0), 25°C, v
$Ca = Ca^{++} + 2e^-$	−2.87
$Na = Na^{+} + e^-$	−2.712
$Mg = Mg^{++} + 2e^-$	−2.34
$Al = Al^{+++} + 3e^-$	−1.67
$Zn = Zn^{++} + 2e^-$	−0.762
$Cr = Cr^{+++} + 3e^-$	−0.52
$Fe = Fe^{++} + 2e^-$	−0.440
$Ni = Ni^{++} + 2e^-$	−0.250
$Sn = Sn^{++} + 2e^-$	−0.136
$Pb = Pb^{++} + 2e^-$	−0.126
$H_2 = 2H^{+} + 2e^-$	0.000
$Cu = Cu^{++} + 2e^-$	0.345
$Ag = Ag^{+} + e^-$	0.800
$Pt = Pt^{++} + 2e^-$	1.2

*Signs of potential employed by the American Chemical Society are opposite to those of this table.

At 25°C, this equation may be expressed:

$$E = E_0 - \frac{0.059}{n} \log_{10} (M^{++})$$

There has been a tendency to use the emf series as though it were inflexible, each metal displacing from solution all metals below it in the series. This condition is usually true for metals widely separated in the series, but it should not be assumed to obtain in all instances. Changes in the potentials of metals in dilute solutions, such as are normally encountered in water works practice, may result in radical changes in the order of potentials given in the emf series.

Such a change occurs, for example, in the iron-zinc system. Zinc is normally anodic (more active potential) to iron, and is used in many piping systems as a sacrificial protective coating for iron. In fresh water with a temperature higher than 150°F, however, it becomes cathodic (more noble potential) to iron and is no longer sacrificially protective[3]. The effective potential of a metal also may be varied by reactions with elements in a given environment. It is evident that the emf series, calculated for unit metal activity, cannot be applied directly to determine the potential of a metal under the conditions normally found in water works practice.

Table 2

GALVANIC SERIES OF METALS AND ALLOYS

Corroded end (anodic or least noble)	Magnesium
↓	Zinc
	Aluminum 2S*
	Steel or iron
	Cast iron
	Lead
	Tin
	Brasses
	Copper
	Bronzes
↑	Chromium-iron (passive)
	Silver
Protected end (cathodic or most noble)	Graphite
	Gold
	Platinum

*"Commercial pure" aluminum.

A galvanic series is one in which metals are arranged in their usual electro-potential sequence in a given environment. Therefore, although there is only one emf series, there may be many galvanic series, each applying to a given set of environmental conditions. In a galvanic series, like the abbreviated example in Table 2, actual potential values are not given, as these vary widely with different environmental conditions[1,3]. Metals that are grouped together in a gal-

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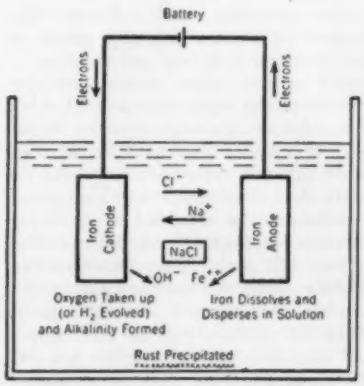

Fig. 1. Impressed-Current Cell

The current flow between the electrodes results in a loss of metal from the anode.

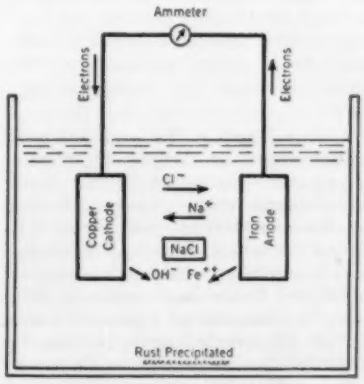

Fig. 2. Galvanic Cell

The reactions at the electrodes are identical with those in the impressed-current cell, but the current flow is due to the difference in the electrode potentials rather than to an external source.

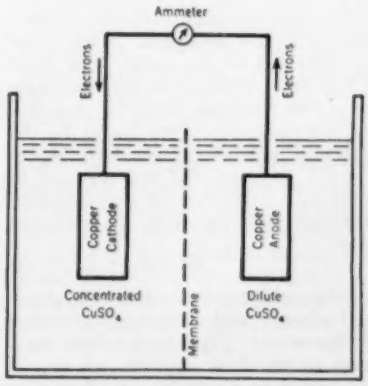

Fig. 3. Concentration Cell

In this type of corrosion cell, the difference in electrode potentials results from the difference in metal ion concentrations in the solutions.

vanic series have little tendency to form galvanic cells, while metals that are widely separated have a great tendency to form such cells when used together.

Corrosion Cells

Many kinds of electrolytic cells are capable of causing the corrosion of metal, but those most commonly encountered in practice may be divided into a few basic types: impressed-current cells, galvanic or differential-metal cells, concentration cells, differential-aeration cells, differential-temperature cells, and differential-stress cells.

Impressed-current cells. It is well known that, in an impressed-current cell (Fig. 1), the current flow between the electrodes results in a loss of metal from the anode in accordance with one of the following reactions, depending upon the current density:

$$Fe^0 \rightarrow Fe^{++} + 2e \quad \text{.....(1)}$$

or:

$$Fe^0 \rightarrow Fe^{+++} + 3e \quad \text{.....(2)}$$

The rate at which the metal passes into solution is directly related to the rate of current flow between the electrodes. Faraday's law states that the passage of 1 faraday of electricity (96,500 ampsec or coulombs) through an electrolytic solution produces one chemical equivalent of some chemical change at each electrode. Therefore, the passage of 1 faraday of electricity between the electrodes in Fig. 1 must cause one chemical equivalent if iron to enter solution from the anode.

One chemical equivalent of change is also produced at the cathode for each faraday of electricity passing through the solution. The primary reaction at this electrode involves the removal of electrons from the metal through neutralization of hydrogen ions in solution:

$$2H^+ + 2e \rightarrow 2H^0 \quad \text{.....(3)}$$

This reaction results in the formation of atomic hydrogen, which tends to plate out on the metal. The layer of atomic hydrogen on this electrode tends to interfere with the transfer of electrons from the metal to the solution and, therefore, must be removed in order for the reaction to proceed. This may be accomplished through the formation of hydrogen gas:

$$2H \rightarrow H_2\uparrow \quad \text{.....(4)}$$

or through reaction between the atomic hydrogen and chemicals in solution in the water. The most common reaction of this type involves the atomic hydrogen and oxygen in solution in the water:

$$4H + 2O_2 \rightarrow 2H_2O \quad \text{.....(5)}$$

Other possible types of reactions between hydrogen and the oxygen in solution have been suggested [1-4]. The neutralization of hydrogen ions in the solution at the cathode results in the production of alkaline conditions in the vicinity of this electrode. The metal ions or salts entering solution from the anode react with alkalinity and oxygen in solution to form iron oxides, known as rust. These oxides may be formed in the vicinity of the anode or cathode, or in a location remote from either electrode.

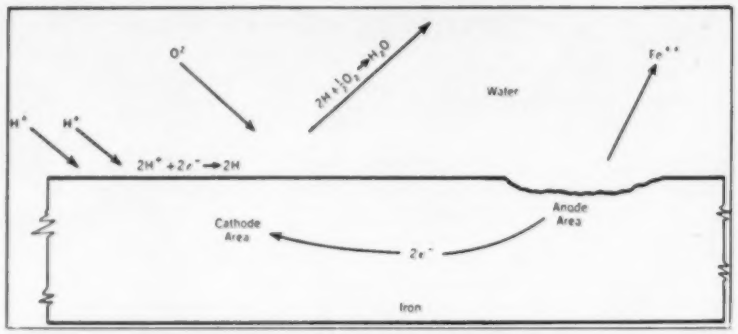

Fig. 4. Corrosion Cell on Surface of Submerged Iron
The surface of a large section of metal may be covered by many such cells, the electrode reactions of which are similar to those discussed previously.

The potential of a metal in water may be changed through the application of impressed currents, causing an increase or decrease in the rate of corrosion of the metal, depending upon the direction and magnitude of the applied emf[5]. This phenomenon can be observed in the external corrosion of pipelines by stray currents and in the cathodic protection of pipeline exteriors and other structures by applied emf.

The corrosion of iron in water usually occurs in the absence of impressed currents. Whitney[6] showed that the corrosion of iron in water is electrochemical in nature, and Evans and Hoar[3] demonstrated that there is a direct relationship between the current flowing between anodes and cathodes on a metal surface and the weight of metal lost from that surface.

Galvanic cells. The emf and galvanic series show that, when different metals are introduced into a given environment, they have different tendencies to corrode, and display different potentials. Figure 2 illustrates such a situation, with iron and copper immersed in the same aqueous solution. Examination of a galvanic series (Table 2) reveals that copper may be expected to display more noble (cathodic) potential than iron. If the two metals are connected electrically, the difference in potentials between the iron and copper results in a flow of current between the electrodes. This may be demonstrated by connecting the two electrodes through an ammeter, as shown, and measuring the galvanic current flow.

In the cell shown in Fig. 2, the iron has the greater tendency to pass into solution, leaving electrons at the metal surface. These electrons pass through the metallic portion of the circuit to the copper electrode and are transferred from the metal to the solution by neutralization of hydrogen ions in the solution. The atomic hydrogen is removed from the copper through the formation of hydrogen gas or reaction with oxygen in solution. In this cell, the iron serves as the anode (electrode at which takes place), while the copper functions as the cathode (electrode at which reduction takes place). The current flow that accompanies the loss of metal from the anode is generated by the difference in potentials between the electrodes in the galvanic cell rather than by an external source of emf as in the impressed-current cell. Therefore, the galvanic cell in Fig. 2 can be considered—and, in fact, is—nothing more or less than a battery. The reactions taking place at each electrode are identical with those described above for the impressed-current cell.

Concentration cells. From the Nernst equation previously given, it can be seen that the potential of a metal in a solution varies with the concentration of its ions in that solution. As the concentration of metal ions in solution increases, it becomes more difficult for additional metal to enter the solution as ions. Therefore, a metal can be expected to display a more noble potential in the presence of a high metal ion concentration. Figure 3 shows two identical copper electrodes immersed in solutions of different concentrations of copper sulfate. As these electrodes are exposed to different concentrations of copper ions, they have different potentials. The electrode in the more concentrated solution has a more noble

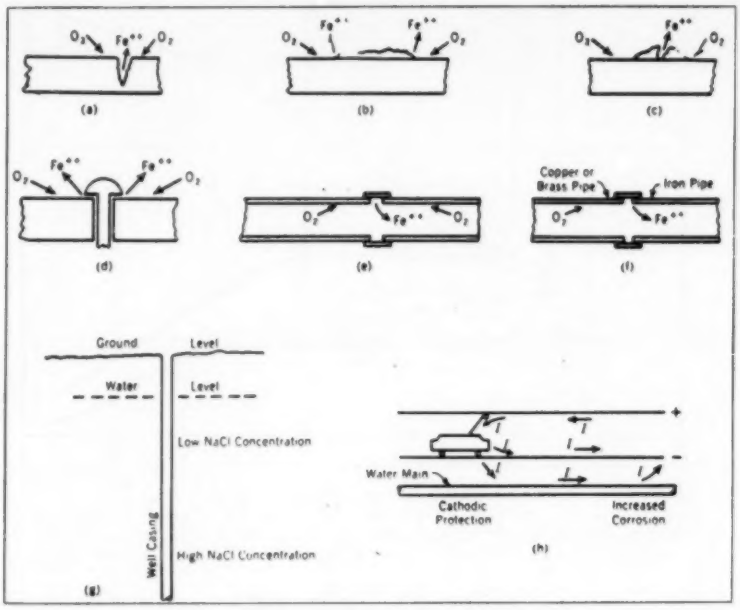

Fig. 5. Typical Corrosion Cells Found in Practice

Key: (a) pit or depression; (b) mill scale or corrosion products; (c) biological growth; (d) rivet or bolt; (e) pipe coupling (same metals); (f) pipe coupling (dissimilar metals); g) well casing in water with varying salt content; (h) stray-current corrosion. The first five are examples of differential-aeration cells; the remaining three illustrate, respectively, galvanic, concentration, and impressed-current cells.

potential and acts as the cathode in the corrosion cell, while the other electrode functions as the anode.

The potential of a metal in solution is affected by the concentration of ions other than metal ions. For example, a concentration cell similar to the one in Fig. 3 can be prepared by using two sodium chloride solutions of different strength. This effect can also be observed with metals immersed in solutions of different substances (acids, bases, salts, or gases).

Differential-aeration cells. A differential-aeration cell is a special type of concentration cell which is of particular significance in the water works field. The rate of the chemical reaction between the oxygen in solution and the hydrogen atoms on the metal depends upon the rate of access of oxygen to the metal surface. Therefore, if one electrode of a corrosion cell receives oxygen at a higher rate than the other, the polarizing layer of hydrogen on this electrode is removed more rapidly. The rapid removal of hydrogen facilitates the transfer of electrons from the metal to the solution at that point, and this area of the metal becomes the cathode of the corrosion cell. The electrode that receives less oxygen becomes the anode of the differential-aeration cell. This electrode suffers an increase in corrosion rate owing to the increased rate of depolarization at the cathode. The significance of this type of corrosion cell in water works practice will be discussed more fully later.

Differential-temperature and differential-stress cells. Differences in temperatures and stresses of metals may result in the formation of corrosion cells. These types of cells may be important in initiating corrosion, but their effects are usually obscured by other, more significant kinds of corrosion cells. Therefore, on a long-term basis, differential-temperature and differential-stress cells are of relatively little importance, under the conditions usually found in water works.

Formation of Corrosion Cells

For the sake of clarity, the electrodes in the cells considered in the preceding section were assumed to be individual pieces of metal. The corrosion of a single submerged metallic object results from the formation of anodes and cathodes on the surface of the metal. Figure 4 shows, schematically, a typical corrosion cell on the surface of a submerged sheet of iron. The anode and cathode of this cell are short circuited by the body of metal. It will be noted that the cell and the electrode reactions shown in Fig. 4 do not differ basically from those which have been discussed previously. The surface of a large section of metal might be covered by many such corrosion cells. The presence of local anodes and cathodes on the surfaces of corroding metals has been demonstrated, and it has been shown that the amount of current flowing between the electrodes and the weight of metal lost can be definitely correlated[6,7].

The formation of a corrosion cell on the surface of a metal may be due to differences in metal composition, electrolyte concentration cells, or differential-aeration, -temperature, or -stress cells. Figure 5 shows a few typical examples of how such cells may be formed in practice. The first five (Fig. 5a-5e) are examples of differential-aeration cells. In each instance, the portion of the metal that has freer access to oxygen acts as the cathode in the corrosion cell, while the portion shielded from oxygen becomes the anode.

Figure 5f shows a galvanic cell caused by connecting pipes made of different metals. Copper and brass are cathodic to iron, and, therefore, the iron pipe corrodes while the copper or brass pipe acts as the cathode in the corrosion cell. Figure 5g shows conditions under which an electrolyte concentration cell may be encountered in the external corrosion of pipelines passing through soils or waters that vary widely in chemical characteristics.

Finally, Fig. 5h illustrates a common example of corrosion by impressed current. If the water main may become part of the return circuit to a power plant furnishing electricity for a streetcar system, the portion of the pipe where the current passes from pipe to ground suffers an increase in corrosion rate. The corrosion rate of that portion of pipe at which no interchange of current takes place between pipe and ground is not affected, and the internal corrosion of the pipeline is likewise unaffected.

The types of cells capable of causing corrosion have been discussed individually, but it must be stressed that two or more varieties may tend to occur simultaneously. For example, the concentration of metal ions under a tubercle (Fig. 5c) could be expected to be higher than in the water surrounding the tubercle. Therefore, consideration of the relative concentrations of metal ions would indicate a tendency toward the formation of a corrosion cell in which the area of metal under the tubercle would act as the cathode. The differential-aeration cell formed by the action of the tubercle in shielding a portion of the metal from oxygen tends, however, to result in the formation of a cell in which the area of metal outside the tubercle acts as the cathode and the area under the tubercle serves as the anode.

Rate of Corrosion

It has been pointed out that the rate of corrosion of a metal in aqueous solution is a function of the rate of current flow between anodes and cathodes on the surface of the metal. The reactions taking place in a corrosion cell have been presented in the preceding sections. It is evident that, in order for corrosion to take place (Reaction 1), the electrons left on the metal by this reaction must be removed (Reactions 3-5). Otherwise, a counter, or back, emf will be built up on the metal, and the corrosion will be stifled. Therefore, in a corrosion cell, the anode and cathode reactions must proceed at the same rate. Any reduction in the rate of the reaction at either electrode must result in a corresponding reduction in the rate of current flow between the electrodes and, hence, in the rate of corrosion of the metal. In practice, the rate of corrosion may be controlled by reducing the rate of the anode reaction, the cathode reaction, or both.

The removal of the polarizing layer of hydrogen from the cathode may be accomplished through hydrogen evolution (Reaction 4) or through oxygen depolarization (Reaction 5). It has been shown by past investigators that, in neutral or mildly alkaline waters, corrosion with evolution of hydrogen at the cathode is negligible, although the relative positions of iron and hydrogen in the emf series might lead to the supposition that the corrosion of iron should be accompanied by continuous evolution of hydrogen. The explanation is that resistance or "overvoltage" must be surmounted before hydrogen can be evolved as a gas from a metal surface. In neutral or mildly alkaline waters, the overvoltage is too high to allow the escape of appreciable amounts of hydrogen gas from iron cathodes. As the pH of a water decreases below a value of approximately 4.0, the hydrogen ion concentration is increased to such an extent that hydrogen evolution is greatly facilitated, and the formation of this gas becomes a major cathodic reaction.

Because the waters encountered in municipal and industrial systems are generally neutral or slightly alkaline, the amount of corrosion due to hydrogen evolution is of minor significance —approximately 3 per cent, according to Speller[3]. Therefore, the primary cathodic reaction in these systems must be the removal of hydrogen by reaction with oxygen in solution in the water (Reaction 5). The anode reaction rate is much more rapid than the depolarization reaction rate at the cathode[3]. As both reactions must proceed at the same rate, it is evident that the rate of corrosion of iron in natural waters is controlled by the rate of oxygen supply to the cathodes of the corrosion cells. The latter rate is influenced by the concentration of oxygen in solution, the rate of flow and turbulence of the water, and the presence of films of oxides or inhibitors on the metal surface. Within the range of oxygen concentrations normally found in municipal and industrial waters, the rate of corrosion increases directly with the rise in oxygen concentration.

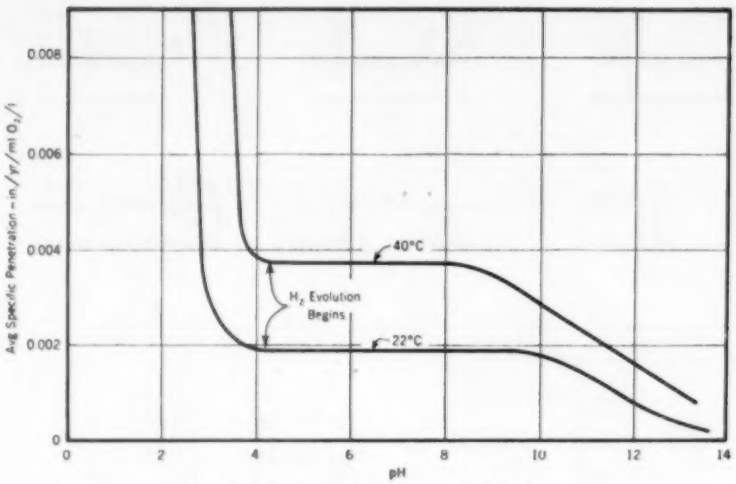

Fig. 6. Effect on pH on Corrosion of Steel

In the pH range 4-10, the corrosion rate depends on the rate of oxygen supplied to the metal surface. Above pH 10, the formation of a layer of corrosion products leads to passivity. Below pH 4, hydrogen evolution becomes a major cathodic reaction.

Uhlig[8] has stated that: "All iron and steel, regardless of minor variations of composition or structure, corrode at the same rate in natural waters." This fact is of great significance to the water works industry, which uses many types of iron and steel pipes for various reasons, some realistic and others not.

The formation of films on the surfaces of metals has a significant effect on their corroding characteristics. The films formed on metals may include layers of hydrogen or oxygen, films formed by chemical reaction between corrosion products and elements of the corrosive environment, and films formed by inhibiting agents added to the corrosive medium. Film formation may occur preferentially at either anodes or cathodes of corrosion cells, or over the entire surface of the metal. Films on the cathodes of corrosion cells may interfere with the transfer of electrons from the metal to the solution. The formation of these films may result from the electrodeposition of positively charged ions or colloidal particles on the cathode, from sorption of chemicals on the metal surface, or from the reaction of some chemical in solution with the alkalinity produced at this electrode, resulting in the formation of an insoluble precipitate on the metal.

Anode films may be formed through electrodeposition of negatively charged ions or colloidal particles on this electrode, through sorption of chemicals on the metal surface, or through the production of an insoluble precipitate by reaction between the iron entering solution and chemicals in solution. The formation of an anode film may result in the effective separation of the metal from the water at the anode, stifling the anode reaction.

Under certain conditions, film formation on a metal may be accompanied by a radical change in the potential of that metal to a more noble value. When a metal undergoes a sharp reduction in corrosion rate, accompanied by a shift in potential to a more noble value, it is said to be "passive."

Figure 6 shows the effect of the pH of the water on the corrosion rate of mild steel in the absence of the formation of protective coatings[8]. The rate is essentially constant in the range of pH 4—10 at 22°C. In this range, the predominant cathodic reaction is oxygen depolarization, and the corrosion rate is determined by the rate of supply of oxygen to the metal surface. As the pH of the water is decreased below 4, hydrogen evolution becomes a major cathodic reaction. The increased corrosion rate at low pH values can be attributed to increased hydrogen ion concentration in the solution and the dissolving action of the water on any protective

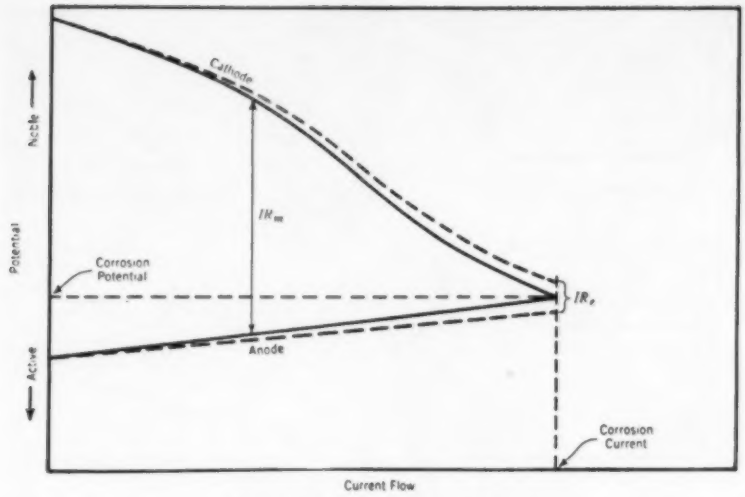

Fig. 7. Typical Polarization Curves

The solid lines represent the curves that would be obtained if the electrode potentials were measured against a "remote" reference cell; the broken lines indicate the curves resulting from the use of "probe" electrodes, located close to the respective corrosion cell electrodes.

layers of corrosion products on the metal. As the pH is increased above 10, a protective layer of corrosion products is formed on the metal, or the surface reaction rate of the iron becomes lower, resulting in passivity of the metal and a decrease in the corrosion rate. The chemicals present in natural waters may have a great effect upon the shapes of the curves in Fig. 6, through reaction with corrosion products and formation of protective coatings.

Polarization

In a corrosion cell, the driving force for the electrical current flow between the electrodes is the difference in potential between the anode and the cathode of the cell. From Kirchoff's second law:

$$\Sigma \text{emf} = \Sigma IR$$

or:

$$E_c - E_a = IR_e + IR_m$$

in which R_e is the resistance of the electrolytic portion of the circuit; R_m is the resistance of the metallic portion of the circuit; E_c is the effective (polarized) potential of the cathode; E_a is the effective (polarized) potential of the anode; and I is the current flow between the electrodes.

The potentials of anodes and cathodes in corrosion cells may vary with the current flow through the cells. This effect is known as polarization and is comparable to friction in a mechanical or hydraulic system. As the current flow through a corrosion cell increases, the potentials of the anode and cathode tend to approach a common value. Polarization of both electrodes would result in a shift in the anode potential in the cathodic direction and a shift in the cathode potential in the anodic direction. Therefore, the potential difference between the electrodes in a corrosion cell through which current is flowing is usually less than the difference in the open-circuit potentials, or potentials of the electrodes with no current flowing. An increase in the degree of polarization of either electrode results in a decrease in the potential difference between the electrodes (or driving force for the corrosion process) and, thus, in a decrease in the rate of current flow in the cell.

The polarizing characteristics of separate anodes and cathodes under a given set of conditions may be determined by varying the rate of current flow between the electrodes (by varying R_m) and measuring the potential of each electrode against that of a standard reference cell. In Fig. 7 is shown a typical pair of polarization curves, indicating the potentials of the anode and cathode of a corrosion cell at various values of current flow between the electrodes. The points at which the curves intercept the ordinate axis represent the open-circuit potentials of the electrodes (no current flowing in the corrosion cell). The intersection of the curves gives the corrosion potential and the corrosion current with the electrodes short-circuited, which is usually the situation in practice. The curves represented by the solid lines are separated by a distance equal to IR_m. These are the curves that would be obtained by measuring the potentials of the electrodes against a "remote" reference cell, or a reference cell located midway between the electrodes. The broken lines in Fig. 7 are those which would be obtained through the use of probe electrodes, located in the immediate vicinity of the respective corrosion cell electrodes. These curves are separated by a distance equal to $IR_e + IR_m$.

It has been stated that the rate of corrosion may be controlled by the rate of the cathode reaction, the anode reaction, or both. Altogether, four types of control are possible in corrosion cells. These are illustrated in Fig. 8. Figure 8a represents the limiting case of "resistance control," in which the current flow between the electrodes has no effect on the potential of either of them; the current flow in the corrosion cell is limited by the IR_e and IR_m of the system, and the potential of each electrode remains constant at the value of the open-circuit potential for that electrode. This situation would never occur in water works practice. Figure 8b represents the case in which the current flow in the corrosion cell is limited by the polarization (change in potential with current flow) of the cathode. In this instance, the corrosion is said to be under "cathodic control." Figures 8c and 8d show polarization curves that might be obtained when the rate of corrosion is controlled by polarization of the anode ("anodic control") or of both electrodes ("mixed control").

It has been pointed out that, in aqueous solutions with no inhibitors present, the anode reaction rate in the corrosion of iron is very much faster than the depolarization reaction rate at the cathode. In neutral or slightly alkaline waters, the rate of corrosion is almost completely governed by the rate of supply of oxygen to the cathode. Therefore, in most municipal and industrial water systems, the corrosion is under primarily cathodic control, as illustrated in Fig. 8b. The rate of corrosion is governed by the degree of polarization of the cathode.

Distribution of Corrosion

The factors affecting the overall rate of corrosion of iron in water have been discussed. Other factors of equal significance are those which influence the distribution of corrosion occurring; the corrosion may take place uniformly over the entire metal surface or be localized, with the entire loss of metal confined to a relatively small area. The life of a metallic structure in water is determined, to a large extent, by the rate of penetration of the structure by corrosion. Localized attack may lead to rapid failure of the structure, although a relatively small proportion of the metal has been lost to solution.

As the rate of corrosion of iron in water is usually controlled by the rate of the cathode reactions, the formation of a protective coating that only partially shields the anode of a corrosion cell from the corrosive medium may have little or no effect on the rate at which metal passes into solution. In these circumstances, incomplete shielding of the anode may lead to a reduction in the effective anode area and to an increased rate of penetration of the metal. This results in more rapid failure of the structure.

Chemical deposits, as well as deposits of biological organisms on the surface of a metal, may result in the formation of tubercles. Tubercles restrict the access of oxygen to the surface of the metal, thereby establishing differential-aeration cells. The metal under a tubercle undergoes pitting attack, while the metal surrounding the tubercle serves as the cathode of the corrosion cell. The anaerobic conditions within tubercles favor the growth of the sulfate-splitting type of bacteria, even though oxygen may be present in the water outside the tubercle. These organisms are capable of utilizing cathodic hydrogen, thus causing microbiological depolarization, and they produce hydrogen sulfide, which reacts with the ferrous metal to form ferrous sulfide[2].

The formation of protective coatings on the cathode of a corrosion cell under cathodic control results in an overall reduction in the rate of metal loss without increasing the rate of penetration of the metal, because the effective area of the cathode is reduced. The formation of protective films on the cathode tends to restrict the access of oxygen to this electrode. Simultaneous removal of corrosion products from the anode of the corrosion cell would result in the formation of a differential-aeration cell, with the shield cathode becoming the anode of the new cell, while the area that was originally anodic but now has freer access to oxygen would serve as the cathode. It is evident that such conditions favor continuous reversals of the potentials of anodes and cathodes on the metal surface. This situation results in a uniform attack of the metal surface over a period of time.

In solutions of low conductivity, the anodes and cathodes are limited in size by the resistance of the electrolytic portion of the corrosion cell. The surface of iron in a water of low conductivity is covered by a large number of small, evenly distributed anodes and cathodes, resulting in a relatively uniform attack on the metal surface. In a water of high conductivity, the cathodic area serving a given anode may be much larger, owing to the lower internal resistance of the corrosion cell. Under such conditions, there are fewer corrosion cells on a given area of metal, and localization of corrosion is increased[2].

Stray electrical currents cause localization of corrosion at areas where the current leaves the pipe. Localized corrosion may also occur near the waterline in storage tanks.

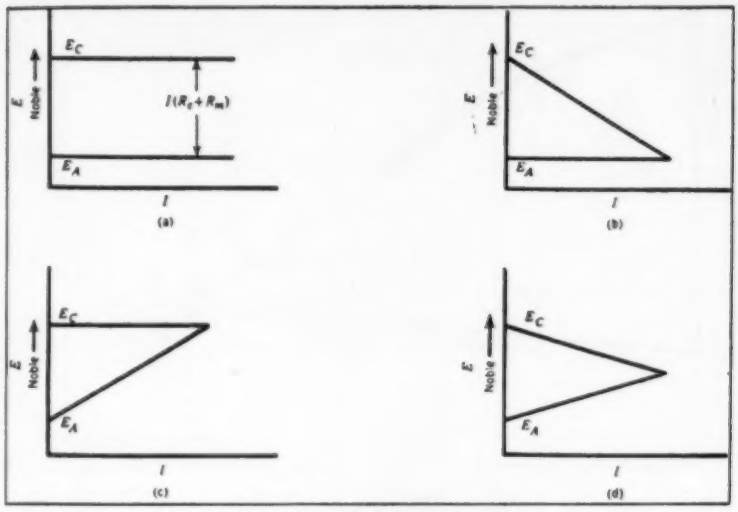

Fig. 8. Types of Corrosion Control

Key: (a) resistance control; (b) cathodic control; (c) anodic control; (d) mixed control.

Summary

The mechanism of the internal corrosion of water pipes is of a very complex nature. The rate and distribution of pipeline corrosion are affected by many variables, a few of which have been discussed briefly.

The evaluation of existing corrosion inhibitors and the development of more effective means for reducing pipeline corrosion are problems of prime significance to the water works profession. The solution of these problems can be accomplished only after a thorough understanding of the mechanism of corrosion and corrosion inhibition has been obtained through extensive research programs. In the light of such knowledge, it should be possible to design laboratory and field tests to evaluate accurately the existing methods of reducing losses through corrosion, and to develop more efficient methods for controlling internal pipeline corrosion.

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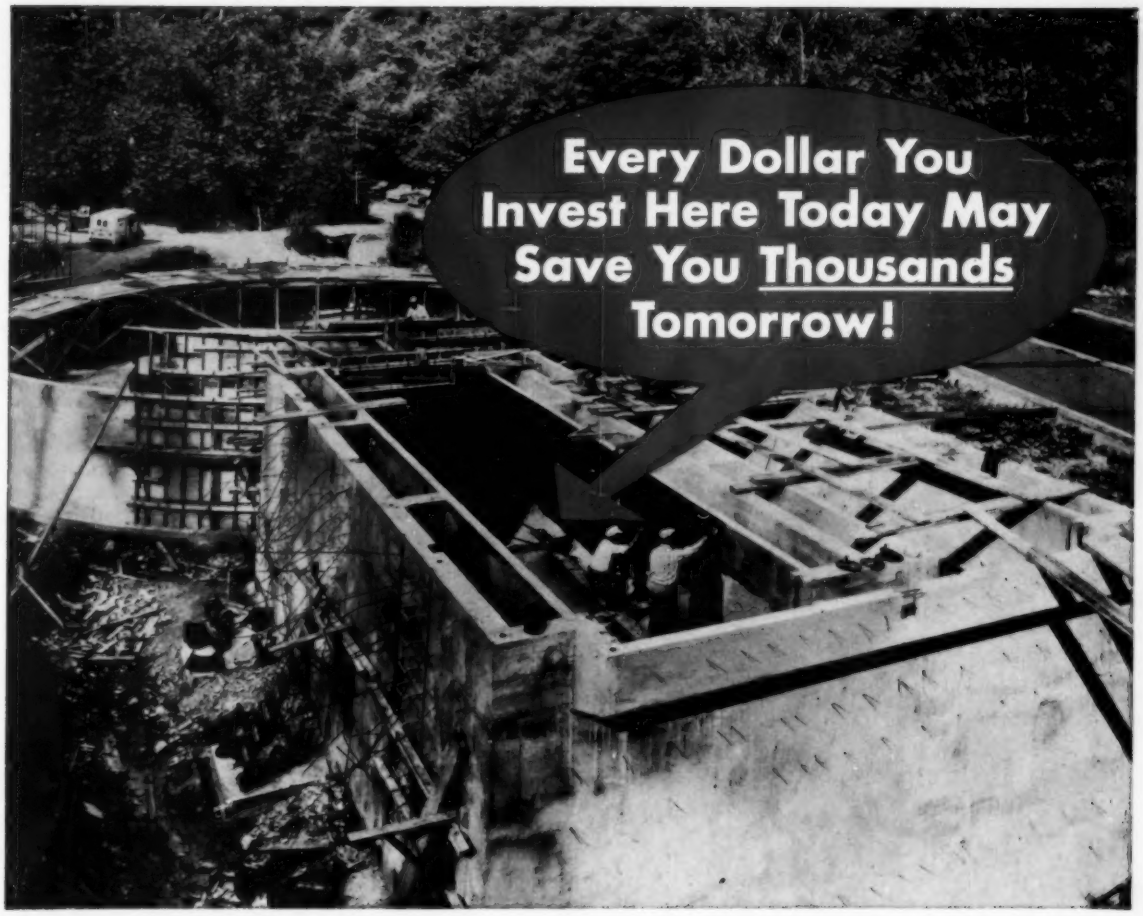

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Membrane Filter in Water Supply Control

by JOHN H. BUSH
Millipore Filter Corp., Watertown, Mass.

AFTER World War II a team of scientists from the Army Chemical Corps became aware of the development in Germany of an extraordinary laboratory device. This was the membrane filter (MF), which had its origin in that country. The Chemical Corps, therefore, initiated research on the device and projected modifications and refinements in the membranes to provide more rapid detection methods for bacteria and other possible agents of biological warfare.

The best defense against a biological attack is quick and reliable detection procedures so that administration of serums and antibiotics may begin at once. Standard procedures were hopelessly inadequate, in that they required four days in some cases and many victims would certainly be beyond help in this period.

The research was initiated and directed by the Chemical Corps at the California Institute of Technology and subsequently with the Millipore Filter Corporation (then a division of the Lovell Chemical Company) on the basic mechanisms involved in producing the membranes, and then on volume production methods.

This research has resulted in the development of a material that appears like paper in that it is white sheet material. It represents, however, an orientation of cellulose-esters in cell or pore walls approaching molecular dimensions. It provides a "screening" device for concentrating particles in the microscopic range in size on a plane surface.

The pores of the MF function as though they were closely packed parallel cylinders of a size of 1/50,000 of an inch in diameter and varying in size by less than 1/500,000 of an inch. These filters may be made to have uniform pores of various diameters by extremely delicate controls in production methods. Thus, separatory screens are available to the laboratory to effectively separate on a plane surface particles which can only be detected with the electron microscope.

Largely through the insight of some of the leading officials in the field of public health, the MF Millipore Filter was released from military security to permit application to problems of public health. A program was initiated to study the feasibility of applying this filter to the bacteriological analysis of water, with the cooperation of the U.S. Public Health Service, The American Water Works Association and the American Public Health Association, together with other interested agencies. This work has been in progress for approximately four years and has resulted in the definition of methods of analysis which are clearly of profound significance in public health control measures.

Use of the filter is one of the simplest possible laboratory techniques: bacteria are concentrated on the surface of the MF when contaminated liquids are passed through the filter. These organisms may be cultured or grown on the surface of the filter when nutrients are provided. Thus the bacteriologist, for the first time, may concentrate organisms from a large volume of liquid and culture them on the filter surface into colonies in order to identify the specific types.

Organisms that are concentrated and cultured in this manner may be counted with the naked eye in as little as 8 hours and positively identified within 16 hours. This is contrasted with other bacteriological culturing procedures, essentially as old as the science of bacteriology, which give comparable results only after four or five days.

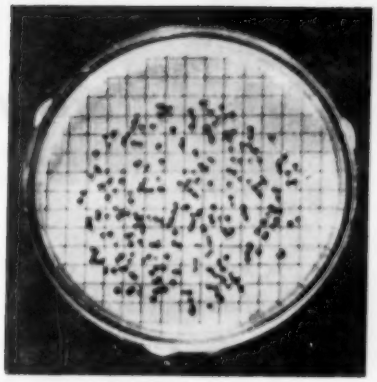
The new MF procedures are much more sensitive, accurate, and reliable than former techniques. In providing earlier detection methods, the Army Chemical Corps has developed a new defense weapon which may be of incalculable importance.

It is worthy of note that in the light of highly exciting possibilities suggested by applying the MF to the bacteriological monitoring of water supplies, the problem of adapting methods was critcally approached with objectivity and a highly proper conservatism.

The MF procedures represent a radical change of methods from those that have been employed over a period of many years. It is significant that highly exacting criteria were used in evaluating results, and that the methods were placed under test with a number of laboratories to establish reproducibility of results under conditions varying with seasonal and geographical factors.

Clearly the official tentative status of the MF method of water analysis which has been announced recently is in anticipation of its standardization. Before the MF method becomes the basis for establishing potable water quality and any complete abandonment of older methods occurs, it is clearly desirable to confirm the validity of results in the hands of a large number of laboratories to be certain

BACTERIOLOGICAL analyses with the membrane filter are routine at the Flint, Mich., Dept. of Public Health



FILTER HOLDER is connected to portbale centrifugal pump for bacteriological analyses of portable waters and sewage. Filters and unbreakable plastic Petri dishes complete the required accessories. Bacteria may be captured, cultured and easily counted (right on the filter surface in a few hours. Differential med a are available.

that no extraordinary circumstances or water conditions are overlooked in evaluating the metthod, and also to establish that the method is workable and gives reproducible results in the hands of technicians in these laboratories. On the latter score the simplicity of the MF method as compared with the MPN (Most Probable Number) method which is now standard, leaves little question.

In the light of the foregoing it would seem that there should be no delay in establishing the MF in the water laboratories. From the standpoint of national defense, it is maintained that a rapid and effective method of monitoring abnormal populations of microorganisms should be established over the country as a whole.

Water is one of the most efficient media for spreading disease. Methods should yield results in a short enough period to permit warnings and/or corrective measures before people become widely infected. The MF would seem to offer the greatest promise for isolating specific pathogens which might be in low concentrations and still be lethal.

More sensitive and controllable conditions of culturing organisms on the MF surface should permit the development of highly selective media. That the responsibility and, in fact, the only hope for the safety of the general public rests with the local laboratories can hardly be questioned in the light of the destruction and failure of communication facilities resulting from saturation bombings experienced in World War II and the incomprehensible devastation possible with A-bomb or H-bomb attacks.

Dozens of State Health Departments and the U. S. Public Health Service have conducted training schools for supervisory personnel and technicians in the water supply field.

In many communities the MF has now been adopted as a routine technique for the examination of source and finished waters, for placing pipelines in service after construction or repair, and for control of stream pollution. In every case the legal minimum of the old MPN tests is still performed. This serves the added useful purpose of affording still more data to correlate the new with the old, while at the same time making full use of the advantages in the new MF techniques. The savings in valuable laboratory personnel time have often permitted much more extensive controls than would otherwise prove practical.

At present, a large number of laboratories investigating widely diverse fields of inquiry are working with the MF to define techniques of application in other fields. It is not possible to predict the ultimate significance of this new tool, but it is now being used in virus research and a wide range of clinical-medical applications. It provides more sensitive and simple methods of monitoring radioactive airborne hazards. In many fields of routine analysis the MF has provided simplified, more accurate and reliable testing methods at a reduced cost.

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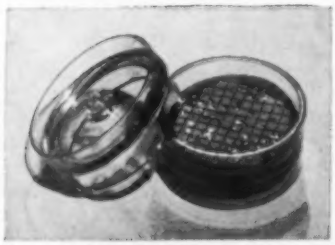
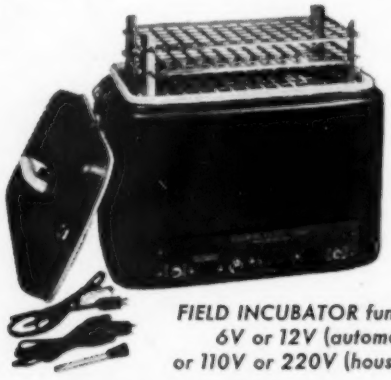


OBSERVATION and IDENTIFICATION

The FIELD MONITOR pre-sterilized closed system, and equipment shown, represents everything required for critical microbiological procedures. Samples may be shipped to laboratory or incubated in the field.



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7. "Closed system" pre-sterilized components insure aseptic procedures.
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The Membrane Filter

Advantages and Disadvantages

by A. M. RAWN and F. R. BOWERMAN

Chief Engr. and Gen. Man. and Div. Engr., Los Angeles County Sanitation Districts.

IN RECENT ISSUES of *Water and Sewage Works* have appeared articles discussing the membrane filter technique for determination of bacterial counts.

One article dealt with the membrane filter in terms of its significance as a simple and accurate means of improving water analysis. Another discussed some supposed inadequacies dealing with the testing of potable waters and tidal bathing areas.

This paper proposes to relate certain experience gained during several years use of the membrane filter, in the hope that it will shed additional light on the subject.

It is certainly correct to note that there are shortcomings in the present state of development of the membrane filter technique. Indeed, most of the articles on the subject have been exceedingly fair and conservative in evaluating the potentialities of this new laboratory tool. One of the best summaries of the advantages and disadvantages of membrane filters for water potability control is contained in a recent report by Thomas, Woodward, and Kabler[1].

Some Objections: Some Facts

With respect to potable waters, objections from some are that large volumes of water must be filtered, that large sample bottles must be used, and that these are impractical for large-scale field sampling and for refrigeration during transportation.

There is no reason why a sample for an MF determination need be any larger than one for lactose-broth inoculation if comparable precision is sought.

Thus, if a 50-ml portion of water contains exactly one coliform, one of the five 10-ml portions in lactose broth will be positive. In comparison, if the 50-ml sample is tested by the MF technique, one sheen colony will be produced. The MPN by the present standard method will be 2.2 per 100 ml (or 10 per cent in error), whereas the MF result will be exactly 2 per 100 ml.

Suppose the 50-ml sample contained exactly 2 coliforms. Both could end up in the same 10-ml lactose tube, giving an MPN of only 2.2 per 100 ml, or 45 per cent in error. On the other hand, the MF would (barring coalescence) still show two colonies, and the count will be 4 per 100 ml, or no error.

A thorough statistical comparison of MPN and MF results is given by Thomas and Woodward[2]. They show that one of the major advantages of the MF technique is the increased precision made possible by filtration of large quantities of water. This advantage in no way detracts from precision in the analysis of equal volumes of water by either method. Hence it is not *necessary* to take larger samples for MF testing, although to do so will lead to improved precision.

In deprecating large samples for field testing and in mentioning difficulties with refrigeration and transportation, one of the unique advantages of membrane filters is emphasized. This new technique lends itself admirably to field testing. Portable laboratories are available commercially (and can be improvised readily) which enable the technician to filter and incubate a sample within a few minutes after it is taken.

Or, the sample can be filtered only and the MF shipped to the laboratory on a preservative medium at ambient temperatures. This procedure is reported by Geldreich, Kabler, *et al*[3] to give results comparable to the MPN test on refrigerated samples examined after 24 hours, and results better than those for unrefrigerated samples.

The Question of Costs

The cost of membrane filters is sometimes cited as a disadvantage. The contention that the cost of materials for an MF test is greater than that of media required for an MPN determination is certainly correct; however, the labor factor and the savings in glassware are overlooked.

In their report, Thomas, Woodward and Kabler[1] state: "The cost of the membranes should decrease substantially as they come into more common use. Moreover, the shorter technician time per test with the MF procedure actually results in an overall cost reduction."

There is no question but that the streamlined MF technique requires less labor per sample than the MPN procedure, and in today's laboratories labor is the major factor in cost.

It is interesting to note in this respect that the adoption of membrane filters in Germany during World War II was brought on largely by the exigencies resulting from mass bombings and the shortage of trained laboratory personnel. With glassware shattered, and incubators at a premium, health departments of several cities such as Hamburg and Stuttgart found true economies of equipment and labor in the MF procedure.

In the testing of non-potable waters the Los Angeles County Sanitation Districts have conducted bacteriological surveys of littoral ocean waters nearby their sewer outfall for over 20 years and have made parallel tests with the membrane filter since early in 1952. To date the Districts have performed over 8,000 membrane filter tests under field conditions and have had ample opportunity to compare labor and material requirements for both lactose fermentation tests and membrane filter tests.

Early results of the testing procedure were outlined in a paper by Goetz, Gilman and Rawn[4]. Later findings have verified the conclusion that more than four times as many hours are required in the laboratory preparing media, tubes and pipettes, reading tubes, transferring inoculations, and washing tubes for the lactose fermentation (MPN) procedure as are required for the same number of tests using the membrane filter.

Additionally, it has proved necessary to use some three to four times the number of pieces of glassware and equipment for the lactose fermentation tests as for the membrane filter techniques. These are based on MPN determination by two parallel four-step dilutions with subsequent confirmation, compared with the membrane filter using an initial enrichment nutrient followed by transfer to Endo's medium.

L. A. County San. Distr. Experience

Field inoculation of lactose tubes has long been practiced by the Districts to obviate the necessity for refrigeration of samples and to avoid additional laboratory work subsequent to the day's testing. Sometimes field inoculation on a pitching, tossing boat on the not too peaceful Pacific Ocean has tested the dexterity and skill of the technician. In fact, on some occasions field inoculation has been impossible.

The membrane filter technique has proved much simpler under such adverse conditions; and glassware breakage, with subsequent loss of samples, has been almost entirely eliminated.

Early testing revealed that some judgment must be exercised by the sampling technician to determine the size of sample most apt to yield a readable count on the membrane filter. This proved no problem when sampling routinely in an area where the approximate concentrations of sewage in sea water may be estimated from experience.

Present procedure is to filter a 10-ml sample within an area of about one mile from the point of outfall discharge, with a 25-ml sample being filtered at all other sampling points.

No necessity for taking decimal dilutions in order to read coliform densities on the membrane filter has proved necessary subsequent to adoption of this sampling technique. Because of the extremely wide range of numbers which can be counted on the membrane filter, it is probable that no more than two widely differing dilutions need be measured on the membrane filter for non-potable waters, unless such waters approach concentrations of bacteria found in crude sewage.

Controversial Aspects

The most controversial aspect of the membrane filter still remains the bacteriological significance of the membrane filter technique using Endo's medium as compared with the lactose fermentation (MPN) test. The Sanitation Districts' fairly lengthy history of parallel testing since early 1952 reveals certain numerical similarities, while, at the same time, revealing some perplexing anomalies.

The question is still considered moot as to whether the *same* organisms are counted in the two tests. There is strong evidence that the membrane filter is selective for *E. coli* in sewage-sea water mixtures, particularly if the coliform organisms have been exposed to the ocean environment for several hours. Since *E. coli* are the particular coliforms considered most representative of pathogen viability, it seems reasonable to say that the selectivity of the membrane filter with respect to *E. coli* is a point in its favor as an indicator of sewage pollution. Additional study will verify or deny this conclusion.

In the meantime, it can be said that the simplicity, ease, convenience, precision, and speed with which the membrane filter test is completed, and meaningful bacteriological levels obtained, have been clearly demonstrated in the field and in the laboratory through almost four years of routine testing by the Los Angeles County Sanitation Districts.

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Measuring Syndets in Water and Sewage

Anionic detergents determined in 30 minutes by color test

By SAMUEL D. FAUST
Chemist, W. A. Taylor & Co., Baltimore, Md.

MANY sewage plant operators have recently reported difficulties in the treatment of sewages containing synthetic detergents. Excessive foaming and inefficient settling seem to be the most common problems caused by these compounds.

There are three categories of detergents: anionic, cationic, and nonionic. Only the anionic need be considered as affecting sewage treatment plant operation because the use of anionic detergents far exceeds any others.

The fatty acid soaps are included as anionic surface active compounds. However the reaction of soap with the calcium and magnesium present in sewage will render it harmless as its detergent properties are destroyed through the formation of an insoluble precipitate. These spent soaps may rise as scum or settle as sludge.

Since synthetic detergents are not affected by calcium and magnesium, nothing in the sewage will cause them to lose their power of detergency. If the detergent concentration is high enough, the sewage solids may tend to remain in suspension. Lowered surface tension of the sewage results in the formation of foam whenever aeration is employed, as described by Keefer.

How to Measure Syndets

With the ever increasing use of synthetic detergents by the public, the need has developed for a simple, reasonably accurate, chlorimetric method for the determination of these compounds. Such a test should be one that a sewage plant operator can easily manipulate. For this purpose, the photometric method described by J. H. Jones has been adapted to the Taylor comparator. According to Jones, "It has been found that 'sulfated' or 'sulfonated' surface active compounds form colored salts with methylene blue. The reaction appears to be:

$$\underset{\text{anion}}{RSO_4^-} + \underset{\text{cation}}{MB^+} \rightarrow \underset{\text{blue-colored salt}}{RSO_4\ MB}$$

These colored salts are soluble in chloroform and under suitable conditions can be quantitatively extracted from an aqueous solution without extraction of any uncombined methylene blue. The amount of surface active compound may, therefore, be calculated from the concentration of the colored salt in the chloroform."

Sewage wastes contain numerous anionic detergents each with a different molecular weight. It was necessary to select as a basic standard a compound whose weight was considered average. Molecular weights of the commercial products tend to concentrate around 250 to 350. We chose sodium lauryl sulfate as the standard because it has a molecular weight of 288 and is available in a pure form. Standard solutions of the sulfate were extracted and the resulting colors were matched by varying the intensity of a stable blue inorganic salt solution. The concentration of anionic detergents varies directly with the color; therefore, as the concentration increases the color increases.

Reagents and Equipment

Reagents for the colorimetric test are: aqueous methylene blue indicator solution, chloroform USP, and concentrated hydrochloric acid. The determination is carried out with a 50 ml graduate, a 10-ml test tube, two separatory funnels (A & B), a glass funnel, a glass stoppered bottle graduated with a 50-ml mark, three 5-ml test tubes, a comparator base and a color standard slide containing standards representing 0, 1, 2, 3, 4, 5, 6, 8, and 10 parts per million of syndet (synthetic detergent).

Procedure

A 10-ml sample of the material being tested is measured with the 10-ml test tube and placed in separatory funnel A. To it is added 10-ml of distilled water and five drops of concentrated hydrochloric acid. After mixing, one milliliter of methylene blue solution is added and the contents of the funnel are thoroughly mixed. To the resulting mixture is added 20 ml of chloroform.

The separatory funnel is shaken gently for one minute and then allowed to stand for five minutes. The chloroform (bottom) layer is then drained into separatory funnel B and 20 ml of distilled water is added.

Separatory funnel B is shaken gently for one minute and then allowed to stand for five minutes. The chloroform layer from B is then filtered into the glass-stoppered bottle through a plug of cotton placed in the glass funnel. The wash water from B is then discarded as this removes the uncombined methylene blue that has been extracted by the chloroform.

To the treated original sample remaining in separatory funnel A is added an additional 10 ml of chloroform. The funnel is shaken gently for one minute and allowed to stand five minutes. The chloroform (bottom) layer is drained into B and 10 ml of distilled water added. After gently shaking for one minute and allowing to stand for five minutes, the chloroform (bottom) layer is passed through the same cotton filter into the glass stoppered bottle.

The operation outlined in the previous paragraph is repeated. Chloroform extractions now total three, one 20-ml and two 10-ml. The funnel and cotton are washed with a small amount of chloroform which is collected in the glass stoppered bottle. The extract is then made up by adding more chloroform to exactly 50 ml in the glass stoppered bottle and is mixed well.

Compare Color With Standards

A dry 5-ml test tube is filled with the blue chloroform solution and placed in the middle hole back of the slots in the bottom of the comparator base. Two other 5-ml test tubes are filled with clear colorless water and placed in the remaining two holes back of the slots in the base.

The color standard slide is placed on the base and holding the instrument toward a source of daylight, the slide is moved in front of the test sample until a match is obtained. The concentration in parts per million of syndet (anionic surface active compound) is then read directly from the values on the slide.

For accurate results the reading should be taken as soon as the extraction and washing procedure is completed. The chloroform solution will decompose in time due to the action of light. The time required to make a complete test is twenty to thirty minutes.

Development of Test

In order to perfect this procedure, it was necessary to extract solutions of numerous commercially available detergents. These compounds can be

subdivided into several groups. Among those studied are:

1. alkyl sulfates: Dreft, DuPont MP 189
2. alkyl sulfonates: Aerosol MA, IB, OT, AY
3. alkyl aryl sulfonates: Ultrawet K, DS, SK bead; Vel
4. alcolol sulfates: DuPonol 80, LS paste, Sufanole FAA
5. amine salt alkyl aryl sulfonate: Sulfanole KA
6. alkyl aryl poly ether sulfate: Triton 771
7. alkyl aryl poly ether sulfonate: Triton X-200

All these commercial detergents were found to react with methylene blue. Accurate data were difficult to obtain because of the use of extenders (such as sodium sulfate), uncertain molecular weights, unknown concentrations of the detergent, etc. However our main purpose was to determine whether or not the colorimetric test could be used over a wide range of compounds. Our conclusion is that the procedure developed is sufficiently accurate for sewage determinations.

Practical Tests on Sewage

Samples of sewage were obtained from several treatment plants and were examined for detergent content as noted in table I. They were submitted both from plants where difficulties are being experienced and from plants having no noticeable trouble.

It may be noted that the test results on samples from Baltimore's Back River Plant correspond very closely to those reported by Keefer. The accuracy of the colorimetric method was verified by taking a 50-ml sample of the trickling filter effluent containing 1 ppm of syndets and evaporating over a steam bath to 25 ml. Extraction was made and a reading of 2 ppm was obtained. Also, known amounts of sodium lauryl sulfate were added to a final effluent sample containing only a trace of detergent. Proper dilutions by adding effluent give to concentrations of 1, 5 and 8 ppm subsequently were verified by extractions.

Additional work is being done at the Hagerstown Disposal Plant under the supervision of Mr. Don Croft. Studies there are correlating the detergent content of sewage to time and rate of flow.

Moderate variations in the amount of methylene blue solution and of wash water has negligible effect on recovery. Enough methylene blue must be used to combine with all the syndet, and the solution in the first funnel must be acid in order to prevent the extraction of methylene blue base which would produce a violet solution in chloroform. The indicator is slightly soluble in chloroform, but a single washing always reduces the blank to a low value. The stability of the indicator solution has been checked over a period of a year, and the indicator was found to be stable if kept in a tightly stoppered bottle.

Basically the syndet comparator consists of a plastic slide housing the permanent standards which are guaranteed against fading and a Taylor pH base to hold the extracted sample for comparison. Reagents, glassware, and a source of artificial daylight are supplied. Principal advantages of the method lie in the simplicity of operation, saving of time and labor, and low cost.

TAYLOR outfit for determination of synthetic detergents in sewage. Color comparator, glassware, and reagents required in 30 min. test

Acknowledgement

W. A. Taylor & Co. wishes to express their appreciation to all who contributed to the development of this equipment; and especially to Mr. C. E. Keefer, Deputy Sewerage Engineer, Baltimore, Md., who brought the problem to our attention. We wish to thank the manufacturers who supplied experimental samples of various anionic detergents and the plant personnel who provided sewage samples.

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Table I

SYNDETS IN SEWAGE

As Measured by Colorimetric Test

Plant	Raw Sewage	Primary Tank Effluent	Trickling Filter Effluent	Final Effluent
Baltimore, Md.	1.5 ppm	1.0 ppm	1.0 ppm	—
Towson, Md.	4.0 ppm	2.5 ppm	1.0 ppm	—
Hagerstown, Md.	2.75 ppm	2.5 ppm	—	1.5 ppm
Bridgeton, N.J.	2.0 ppm	—	—	—
Collingswood, N.J.	4.0 ppm	2.5 ppm	—	1.8 ppm
Barrington, N.J.	7.0 ppm	—	—	3.0 ppm
Gloucester City, N.J.	1.8 ppm	—	1.0 ppm	—
Westmont, N.J.	5.8 ppm	—	—	—
Woodbury, N.J.	3.2 ppm	—	—	—

V. WATER WORKS OPERATIONS

ANY MAN charged with the supervision of water works operations must be a man of many talents. From the procurement of the supply to ultimate delivery of the water to the user, operation of a water works system utilizes many sciences, both pure and applied. Among the better known are physics, chemistry, hydraulics, engineering of all kinds, and bacteriology. Among those perhaps less recognized are limnology, psychology, economics, statistics and many others.

Source of Supply

The ultimate source of water is the ocean from which water evaporates to form clouds, from which, in turn, water precipitates as rain, snow or hail. From this precipitation all water supply for human use is derived.

The amount of water falling on the United States in a year reaches a fantastic figure of 432 trillion gallons per year. More than 72 per cent of this amount evaporates leaving less than 28 per cent to seep into the ground or accumulate in the surface, (about one-third remains in the underground strata).

Unfortunately the precipitation of rainfall (and storage) is not equally distributed throughout the United States. For instance, 60 per cent of the U. S. receives less than 30 per cent of the total precipitation. Thus, the basic reason for water shortages in various sections is evident.

In surface water supplies, the greatest source is streams and rivers, although ponds and lakes also serve as ample sources in many instances. On streams and rivers, impounding dams are used to create artificial lakes or reservoirs to capture stream flow excesses during rainy seasons and store them for use in dry weather.

The construction and operation of impounding reservoirs embraces such factors as yield, site preparation, required capacity, evaporation losses, siltation, effect of storage on water quality, water shed sanitation and other problems.

Ground water results from percolation of rainfall into the ground until it reaches an impervious stratum. The quality of ground water depends on the substances with which it comes into contact during percolation or lateral movement in aquifers.

Ground water may be taken for water supplies from springs, shallow wells, infiltration galleries, or deep wells. The location and construction of wells requires a specialized knowledge of geology, as well as considerations of sanitary conditions, the spacing of wells, well drilling, and protection. Operation of well supplies involves considerations of capacity, ground water flow, development protection against pollution and maintenance of output.

Treatment

Natural waters are never pure in the chemical sense; they may contain dissolved gases and solids, suspended matter and living organisms. When the presence or concentration of these foreign matters in water, makes it undesirable for human consumption or industrial use, it must receive treatment. The kind and extent of that treatment is dictated by two considerations; the use to which the water will be put and the concentration of the foreign matter to be removed.

In the case of surface supplies, water may contain all of the types of foreign matter mentioned; ground waters, on the other hand, usually are free of turbidity, color, taste, odor and bacteria, but may contain dissolved solids and gases.

To render a water potable means to make it acceptable for drinking; in short, to make it clean, clear, and free of harmful bacteria, taste, and odor. It is not necessary to remove all dissolved minerals to obtain drinking water. (in fact, sometimes, removal of dissolved minerals is undesirable). Industrial waters, however, may require extensive treatment, particularly where the water is used for chemical processes or boiler feed.

It is apparent that water treatment consists of techniques for removing these undesirable foreign matter constituents. These techniques involve several processes: coagulation, sedimentation, filtration, disinfection, taste and odor control, water softening, corrosion control, and iron and manganese removal. Not all of these processes are utilized in every water plant, but collectively these processes are called water treatment. The successful operation of these processes produces the quality of water desired, but proper operation depends on careful laboratory control.

Distribution

After water has been procured and treated, if necessary, it is transported to the point of use. This transportation is accomplished through a distribution system consisting of distributing reservoirs, transmission mains, distributing or arterial mains, minor distributors, laterals and service pipes.

Booster stations, valves, hydrants, flow meters, and consumer meters are accessories to a distribution system. All parts of a system must be designed to supply the demands put upon it under conditions of greatest possible use, which means under conditions of fire fighting requirements.

Operation of distribution systems covers such problems as sizing and installing mains, and services, waste water and leakage, loss of carrying capacity, cleaning and lining, etc.

Other Operations

In addition to these main topics of source, treatment and distribution, the water works manager or superintendent must be familiar with pumps and pumping, flow measurement, instrumentation and control, corrosion control, laboratory control, and management. Discussions and articles on these various phases of water works operations are found in appropriate sections in the Reference and Data Issue of *Water & Sewage Works.*

Our Dwindling Clean Water Supply

How water shortages affect our municipal and industrial expansion

by RALPH E. FUHRMAN

Exec. Secy., Federation Sew. & Ind. Waste Assn., Washington, D. C.

TO ONE easily disturbed, the thought of a dwindling water supply may easily lead to a cry of "wolf." While such a cry may seem almost necessary in some cases to arouse the citizenry, we may be thankful that such tactics are not often resorted to, since they accomplish very little toward the solution of an engineering problem. A more rational approach prevailing among engineers faced with the solution of a difficult water supply problem would include a thorough analysis of the quantity and quality of available supplies, along with the cost of the most advantageous solution.

Water and Our Economy

An article in the March 1954 issue of *Fortune* magazine reviews dramatically the national water situation, particularly as it relates to industrial needs. Francis Bello has prepared this audit of water resources.

To maintain the average man in the United States requires about fifteen hundred tons of fresh water per year. Of all other materials—food, fuel, metals, plastics, lumber, sand and gravel—a man requires only about eighteen tons. About one-third of this total amount of water is lost in plant transpiration and evaporation, while the remainder is returned in volume, if not in cleanliness, to the nation's streams. The total amount of water, fifteen hundred tons per year per capita, does not include the volume (seven times as great) used in the generation of hydroelectric power.

Water is unquestionably the cheapest commodity sold by quantitative measure. If necessary to demonstrate this to yourself, try to lift a penny's worth of it sometime. Before such an effort, however, I suggest a thorough physical examination and perhaps a mental examination by competent members of the medical profession. Even at the substantial rate of twenty cents per thousand gallons, your "penny's worth" would weigh over 400 pounds.

Division of Water Industry Costs

In our billion-dollar-a-day national economy, total costs of water run much less than one per cent, with the city dweller's share approximately one-seventh of one per cent or $500 million per year. Agriculture's share of the cost is less than half of the city dweller's. The remainder of our $3 billion national water bill is borne by industry.

Another measure of the size of the water industry is the huge investment in water supply and distribution facilities. At the present time this amounts to about forty billion dollars, of which $7.5 billion represents public supplies. The low ratio between annual income and the investment necessary to produce it, has been cited as one reason for the reduction in privately-owned water systems and the increase in publicly-owned systems.

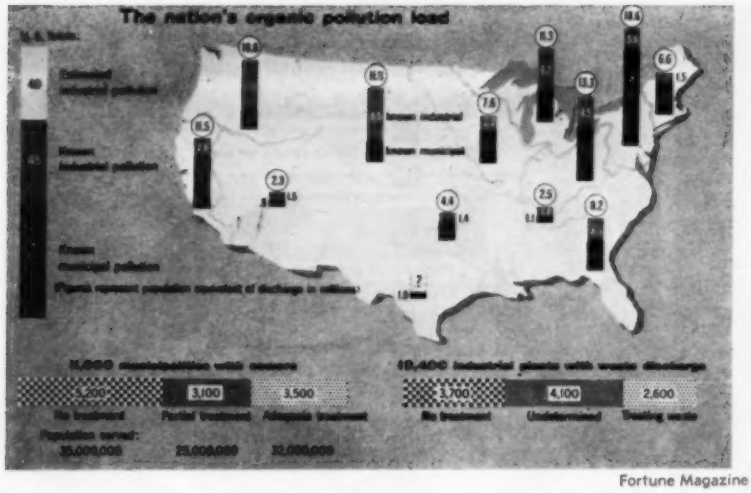
On a national scale there is no need to feel that the United States is running out of water. At the same time it must be appreciated that the seventeen western states are using about seventy per cent of all the water they may expect to develop at reasonable cost. Arizona is using more water than is available within its borders. California has considered bringing water from the Pacific northwest to meet future demands. Texas is considering bringing water from the Mississippi.

At the present time, in many parts of the United States, it is necessary to practice conservation measures that are completely unknown in other parts. The natural emphasis placed on water shortages, like the New York City case of 1950, may lead to hasty conclusions if applied to other places without thorough analysis.

Water Supply—National Problems

In very recent years there have been several significant efforts at portraying the overall problem of water supply for the United States on a national basis. In 1950 the President's Water Resources Policy Commission issued its voluminous report entitled "A Water Policy for the American People." In June 1952 the President's Materials Policy Commission studied the materials problems of the United States and their relation to the free and friendly nations of the world. Such a study necessarily included a consideration of water resources. These primary studies, supported by more detailed investigations and reports by the U. S. Geological Survey and the U. S. Public Health Service, give a plentiful supply of information on this subject.

The mid-century conference on resources for the future held in Washington during December, 1953, included one section devoted to water resource problems. All of these reports should be required reading for industrialists and engineers who have or ever may have water supply problems. The reports present data like those just stated, but also point out that information is incomplete, par-



Fortune Magazine

POLLUTION load of municipalities and industries, based on oxygen depletion.

ticularly as to non-consumptive water use. Even with this shortcoming, we must accept them as the best available until the future brings additional information.

President Truman's Materials Policy Commission concluded that by 1975 the United States may be using as much as ninety per cent of all water than can be developed at reasonable cost. Apparently this conclusion did not differentiate between the consumptive and nonconsumptive uses of water. The ordinary municipal and industrial use of water is nonconsumptive, that is, substantially equal volumes are discharged to surface streams after use.

On the contrary, irrigation returns to streams or groundwater only about one-third of the volume used; while the remainder is lost through evaporation and transpiration. The Policy Commission estimated that the 1975 water demand would be nearly double the 1950 water demand. The increase in irrigation expected for the same period is substantially less. Much of the increase is expected to come from the cooling water requirements of electric generating stations; such stations are expected to quadruple in capacity during the 25-year period. Fortunately, this use does not diminish the water supply; but it does return the water to the stream at an elevated temperature. Though this factor cannot be considered desirable, we are far better off to have temporarily warm water than to have no water.

Regional Aspects of Water Supply

As described in the *Fortune* article, there is a great difference between the demand and supply pictures when the seventeen western states and the thirty-one eastern states are compared. For this comparison, the Louisiana to Minnesota column of states and all those eastward are differentiated from the western states. The average annual precipitation on the whole United States is 4,300 bgd (billion gallons daily). The average runoff and percolation is 350 bgd divided between the 17 western states, and 900 bgd divided between the thirty-one eastern states..

About two-thirds of the western states' run-off is, unfortunately, concentrated in the Pacific Northwest—a long way from arid southern California. Based on a 1950 U. S. Geological Survey Study, the seventeen western states use about 77 bgd for irrigation. This is nearly equal to the East's total use of 80 bgd. Of the 350 bgd in the seventeen western states 120 bgd, or thirty-four per cent, are considered to be economically available. Since 50 bgd are used consumptively, and 35 bgd are used nonconsumptively, an additional 35 bgd could still be developed at a reasonable cost.

In the 31 eastern states, a somewhat brighter picture is presented. Of the 900 bgd total runoff, 225 bgd or 25 per cent are considered potentially available with 80 bgd as the present use. Of this, only 7 bgd are used consumptively. As the result, the remaining 73 bgd are potentially available if a combination of hydrowaste treatment, with or without natural purification, will allow further use of this water. The increased potential of new supplies available is 155 bgd in the eastern states.

Increase in Water Needs

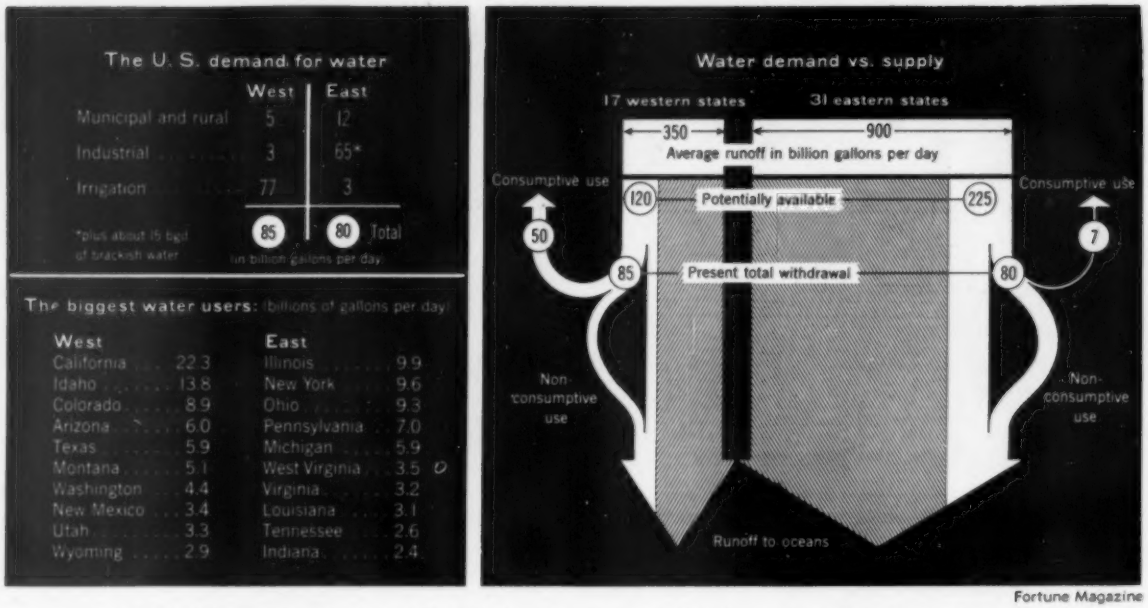
In the twentieth century the withdrawal of water in the United States has about doubled on the average of every twenty-five years. We should have a wholesome concern about our clean water supply. The withdrawal of water is unlikely to double in all parts of the country by 1975, but it appears that increasing per capita consumption to support our constantly rising standard of living will impose this overall demand on water supplies. We may do well to inquire into the possible methods of meeting such a situation. In the parts of our country where water resources can supply this additional withdrawal there is no problem. In other parts of the country it appears that more and more future water needs must be solved by recirculation, reclamation, or, in general, the better use of existing supplies.

The West must decide whether it wishes to use its water resources for the comparatively low value of products produced by irrigation or whether it will prefer to use its water in the production of goods with greater dollar value per gallon of water used. The East must make decisions as to the extent that cities and industries will be allowed to continue the whole sale defilement of streams by pollution.

Methods of Water Conservation

Reclamation of used water is generally practiced only where reclamation is cheaper than the cost of additional supply. One of the best examples of this practice has been the reclamation of Baltimore sewage plant effluent by the Bethlehem Steel Company for use in steel production at the Sparrows Point Mill. The steel mill adopted this practice as the result of an extreme ground water shortage caused by over-pumping in the area. While present use amounts to about 60 mgd (million gallons daily), plans are being made to reclaim the entire volume of treated sewage of the City of Baltimore, approximating 150 mgd.

Surely an outstanding use of water conservation and reclamation is that of the Kaiser Fontana Steel Plant near Los Angeles. This plant draws on local ground and surface waters as well as sewage from the nearby community. At a result, the mill produces steel with a water use of only two per cent of the conventional 65,000 gallons per ton of steel. The technical literature in recent years



Fortune Magazine

WATER CONSUMPTION in the United States (left), and a comparison of water demand with water supply (right).

records many such examples though on a smaller scale.

Increasing regulation of streams by the construction of impounding reservoirs is likely to provide a large portion of our expanded water needs in the next 25 years. In the East, particularly, significant additions to available water supplies would result from this practice.

Ground Reservoirs are Important

The development of new ground water reservoirs is possible even though we hear much about overdrafts of ground water in many locations. In these locations an equilibrium of inflow and outflow will have to be established. Many areas where ground water reservoirs could be tapped are, unfortunately, not in areas which have available the other ingredients for a good industry location besides water—namely labor, markets, and raw materials. The usefulness of ground reservoirs can be increased tremendously by the use of artificial recharging. While this method helps sustain the volumes available, it may also make much greater volumes available by preventing the intrusion of salt water along the Atlantic, Pacific and Gulf coasts.

Other means of augmenting future water supplies include importation of water from an area where it is plentiful, induced rainfall, the production of fresh water from sea water by distillation or iron exchange, or the use of substitutes for fresh water. In the case of the latter, salt water may be used for cooling if the cost of fresh water is too great. Air cooling offers another possibility, as does the use of closed circuits for cooling purposes.

Municipal and Industrial Expansion

The effects of the nationally diminishing water supply have, in the current industrial boom, been most favorable economically to the southeastern United States. The effects on municipal and industrial expansion can hardly be separated. Since industry is the principal reason for the development of cities, municipal and industrial water supply problems tend to merge.

The Materials Policy Commission pointed to the potential additional water supplies as being proportionately greater in the nine southeastern states than in the twenty-two northeastern states. These southeastern states include Louisiana, Arkansas, Tennessee, Mississippi, Alabama, Florida, Georgia, South Carolina, and North Carolina. Availability of water has undoubtedly played a vital part in the South's industrial growth, which reached the astounding rate of one new multi-million dollar plant during each working day of 1951. A glance at this area is sufficient to observe the strong shift from the traditional agricultural economy to an industrial economy.

Another aspect of the renaissance of the South is less obvious but of great importance. That aspect is industrial research which has actually pointed the way for the great industrial expansion. Such research must become and remain mindful of the obligations in the field of water pollution. This does not mean research only to study treatment methods to which hydrowastes will respond; treatment should be the last resort. The fundamental good for the conservation of all resources of the region would be accomplished most by use of processes which (within the limits of economy) would reduce waste to a minimum. The next choice would be to use processes yielding usable byproducts.

It is my hope that sourthern industries and the private as well as public research laboratories in the south will do their very best to develop technological information essential to the solution of stream pollution problems. It is my further hope that southern industries and municipalities, as well as state and regional water pollution control authorities, will cooperate toward the same end. If this course is followed, the ceiling of ultimate industrial development of the region will be raised greatly. If it is not, most of those present may live to see the degradation of southern streams to an extent characteristic of other parts of our country. The Materials Policy Commission suggested that by 1975 water supply may be the most important factor affecting industrial location.

Quality Control of Water From Watersheds

by ALFRED T. NEALE, and E. F. ELDRIDGE

Respectively, Assoc. Engr. and Ch. Engr., Wash. Pollution Control Comm., Olympia, Wash.

WATERSHEDS are the source of a great many municipal and industrial water supplies. Many of these watersheds exist today in the same condition as they did before their use by human beings. Hundreds of millions of gallons of water are used daily by communities and industries. In some cases, only the barest minimum of treatment or purification is necessary to provide a quality of water suitable for these purposes. A great many watersheds have been partially or completely logged. The cut-over lands are in various stages of regrowth, or have been converted to other economic uses. The protection of these water supply watersheds is becoming more and more important as water demands increase and as it becomes necessary to look to surface sources to supply this demand.

In the economy of some areas, the effect of watershed activities on the natural spawning and development of fish is of equal importance to the effect on water supply. The problem also involves flood control, industrial and agricultural uses, and the water rights of many small water users. The need for control exists in the upper reaches of the drainage basins, if adequate protection is to be given to the varied uses of these watershed waters.

Activities Influencing Water Quality

The continual industrial development and the rapid growth of communities demand increasingly larger quantities of high-quality water. Considerable concern is expressed by certain watershed managements regarding the problems arising from the increasing use of the watershed by the public, and especially by highways and railroads. These activities tend to affect the sanitary quality of the water, as well as its physical characteristics, such as color and turbidity.

In many cases, however, activities associated with the logging industry have by far the greatest effect on water turbidity and, in some cases, water quality. The reason for the great bulk of sediment which is carried downstream from logged watersheds is often due to improper location and construction of road systems. This is not necessarily deliberate on the part of logging companies, but is due largely to the lack of understanding of the over-all problem. Road location is often chosen without regard to water interests. Roads are built on the edge of stream channels and the overcast material is dumped in the stream. Often drainage methods are improper, culvert spacings unsatisfactory, and no attention is paid to soil stabilization.

Other logging operations which affect water quality are unsatisfactory yarding methods, and the deposition of slash and debris in channels. Soil leachings from areas which have been burned over contribute to color and sediment to some water supplies. Barriers, impassable to fish migrations, are formed by debris in channels. The barriers so formed have been known to remove large areas of spawning beds from production.

Other activities which may impair water quality from watersheds are mining, gravel operations, improper agricultural methods, grazing, and some recreational activities. Railroads, hydroelectric power and flood control projects may also contribute to the watershed problems.

It is not expected that these activities will be discontinued in order to protect the quality of waters supplied by the watersheds. This obviously is not reasonable or possible except in certain cases where the watershed is completely owned by the water user. Even in these cases, complete elimination of watershed uses is not always feasible or desirable.

Suggested Control Measures

Certain reasonable corrections, however, can be made which will afford at least partial protection of the water quality. Such corrections have been accomplished in many watersheds. Methods of logging and road construction have been altered with the result that the water supply was improved. Other cases of correction have been achieved in watersheds above fish spawning areas. Much more correction is needed, however. It is the primary purpose of this paper to suggest methods by which watersheds supplying water for fisheries, hatcheries, and other uses receive adequate protection. These suggestions are based on methods already in use, or advanced as a result of studies made of various problems. For the most part they should be considered as constituting the minimum requirements. All suggestions will not apply to any one watershed, but will need to be adapted to conditions. In some cases they may not provide adequate protection, and more detailed requirements may be desirable.

Sanitation Measures

1. Portable chemical toilets should be provided for isolated work groups, such as temporary logging camps. Effective sewage treatment and disinfection facilities should be provided for permanent and semi-permanent installations in watersheds.

2. Other temporary camps [for sheep herders, hunters and fishermen, small mining operations, and campers] should provide subsurface waste disposal facilities located at an adequate distance from flowing water.

3. On water supply watersheds, periodic inspections of sewage disposal facilities and their operation by competent personnel should be a part of the water quality protection program.

4. Additional sanitation requirements are necessary for transcontinental railways operating in one or more of the major water supply watersheds. The sanitation problem arises when, in the wintertime, sewage solids become frozen to the car undercarriage. These solids are later deposited upon the tracks and on bridges in the watershed area. They then may find their way into the watercourses by action of snowplows or by subsurface runoff. A way of correcting this problem is to install holding tanks with sufficient capacity on cars to allow for disposal to municipal sewer systems at the various railway stations and terminals.

Erosion, Turbidity and Silt

Much can be accomplished to preserve the productive values of surface waters if continued consideration is given to the erosion problem from the initial planning stages until the watershed logging operations have been completed.

This article by Messrs. Neale and Eldridge will be of interest to those engaged in the field of water supply and also to those concerned with pollution control. Watersheds seldom are entirely owned and controlled by water departments. Where ownership either is private or by state and Federal agencies, control must be supported and sometimes initiated by pollution control agencies. In addition, watershed protection involves implications beyond water supply alone.

The location both of the road network and of the various cutting areas in relation to the entire watershed should be established in advance in such a manner as to minimize the disturbances to the terrain. This practice will lessen the problems of siltation and erosion. Cutting boundaries, landings, and spur roads should be laid out with due regard to conditions of topography, soil and climate, in order to avoid disturbance to stream channels. Also, the effects of snow accumulation and melt must be taken into account to handle drainage, so that muddy water is kept out of channels.

Logging Roads

Some of the factors which should influence road location are the stability of the parent rock, soil overburden, and the texture and drainage characteristics of the soil. Roads should be located away from stream courses and long, steep gradients and excessive cuts and fills should be avoided so as to protect both the stream and the road embankment. Consideration should be given to locating roads on benches and ridges where they are less apt to adversely influence water quality and where road maintenance will be facilitated.

Certain features of road construction can adversely affect water quality unless precautionary measures are followed. Excess dirt and debris should never be deposited directly into a flowing stream, nor placed below the high water level of the channel, since it will eventually be washed downstream during subsequent flood conditions. Cut slopes should be properly graded so as to reduce the slump hazard. Large, unstable cut-and-fill slopes should be mulched and seeded in order that vegetation will become established rapidly and erosion losses will be minimized. Roads should be built only in dry weather to reduce the effects of soil disturbances and to avoid the direct introduction of muddy and silty waters to flowing streams. When necessary, road surfaces should be adequately ballasted to prevent the accumulation of muddy and turbid waters which can drain to adjacent water courses.

Road Drainage

The proper use of culverts on logging roads is an important phase of the problem to minimize stream disturbance. General recommendations for the use of culverts are as follows:

At all road crossings, culverts should be installed unless the fills are sufficiently permeable and stable to permit minor storm flows to pass through without erosion and siltation. Wherever it is possible, drainage should be routed to bench areas for settling. Drainage also should be routed below unstable areas to avoid saturation, slumping and erosion.

In placing culverts, care should be used to prevent excessive channel disturbances and to keep fill material away from culvert inlets and outlets. Culverts should be large enough to carry the greatest flow expected during a 10-year period; it is expected that different rates of flow will be noted for different areas and climates. Culverts should be set on the natural slope and extended well beyond the fill slopes.

Headwalls should be used at the ends to prevent fill erosion into the culvert, and permanent rock or a metal outlet apron should be used to disperse the flow and to prevent gullying. Large culverts should contain a series of steps or should be designed in accordance with fishery department standards in order to allow for the passage of migratory fishes in search of gravel spawning beds. Large culvert inlets should be inspected and cleaned if necessary prior to the annual rainy season so as to prevent clogging and a subsequent washing away of the entire fill.

Logging Operations

Logging methods and types of equipment used are important factors affecting the soil cover and stream channels. Unwise procedures may degrade water quality.

Recommended logging practices include the use of streams to locate cutting boundaries in order to prevent excessive disturbances to stream banks and channels. In areas subject to severe erosion, only small cutting areas should be developed in the vicinity of streams and creeks. Buffer strips at least 30 feet wide should be left along channel edges and low-value stumpage growing on steep pitches adjacent to the channel should not be logged. When logging near channels, trees should be felled uphill, and slash and debris should be kept out of water courses.

Depending on topography and soil conditions, there are many instances in which high-lead cable logging uphill is desirable from the standpoint of water quality protection. To prepare for the times when it is not possible to lift logs across channels by means of a slack line, cables should be installed as temporary measures in order to prevent disturbances to stream banks and the formation of log jams.

Tractor logging should, if possible, be limited to areas of less than 15 per cent slope where soils are heavy or highly erodible, and tractors should not be used when the ground is saturated or where the slope is over 30 per cent. Only a few turns should be brought in over each skid trail, to avoid deep gouging and channelizing. When yarding across channels with tractors, use should be made of temporary, removable log or metal culverts.

Skid trails should be drained at short intervals, especially during the rainy season, in order to divert water away from landings. The use of catch basins or the diversion of drainage to flat areas below landings is often desirable to prevent silt and mud from directly entering streams and rivers. It is imperative that skid trails should not be run in channels or down channel banks.

During and after logging, small slash should be thrown into skid trails and scattered on landings, thus providing a mulch to reduce erosion. This small slash also provides shade to encourage rapid re-establishment of plant cover to hold the soil. In many instances it is desirable to seed bare areas of disturbed soil with grasses and legumes to provide a quick cover crop.

It is imperative that cross drains or water bars be installed in the steeper, abandoned skid trails and spur roads to prevent high drainage concentrations and severe erosion. Dispersed waters should be either spread to allow a filtering action or conducted to flat areas for settling before reaching flowing creeks and streams.

Many of the basic features presented under logging road construction also apply to other road and railroad construction, including State and

county highways. Consideration should be given to the soil types encountered in the watershed. Precautions should be taken to minimize the ground disturbance. Satisfactory and adequate methods should be employed for the control of erosion and for the prevention of sedimentation and turbidity in the streams of the watershed.

Flood Control Projects

Dams and flood control projects should be considered a part of the watershed program since they usually are undertakings of considerable size which may degrade the quality and productivity of natural waters. Variable-level outlets are necessary at these structures in order to minimize unsatisfactory temperature and turbidity conditions downstream from the dam.

To prevent wave erosion and turbidity, cover crops may be desirable on the flowage areas of reservoirs where water levels may fluctuate widely. Areas subject to submergence up to 3 or 4 months should be seeded with reed canary grass. Areas subject to submergence up to 2 or 3 weeks should be seeded with meadow foxtail or smooth bromegrass.

Mining access roads should be constructed in accordance with the provisions recommended for logging roads so as to prevent the development of erosion and conditions of siltation and turbidity. Sluicer-type mines, process mines, coal and gravel washing operations should provide for adequate settling of tailings prior to their discharge to a watercourse. Toxic wastes, if present, should be treated in accordance with the pollution control authority recommendations.

Grazing Operations

Grazing can be completely prohibited on domestic water supply watersheds where the municipality owns or controls the entire watershed. On other watersheds, it should be controlled by fencing, patrol, salt distribution, and seasonal regulation. A grazing management plan should be set up for any watershed where this use is of importance. The plan should include an inventory of the grazing resource by ownership, and a record of grazing use. Type and numbers of stock intensity of grazing and entrance and exit time are important factors. The plan should also include such sanitary control features as location of stock driveways and bedding grounds, and a patrol to remove dead animals. Stock watering should be accomplished by troughs located away from the stream bed.

Periodic inspections should be made to determine the effects of grazing on soil conditions and erosion. In the event stream crossings are necessary, they should be accomplished in a minimum length of time. Where inspection shows that the presence of large numbers of big game animals are factors in overgrazing, soil trampling and compaction, and erosion, consideration should be given to effective population control measures.

Recreational uses should generally be restricted or very carefully regulated on water supply watersheds, since large numbers of people on a watershed can create problems of pollution and sanitation as well as a fire hazard. On many water supply watersheds, a permit system of entry is used, with the entrant being given a copy of rules and regulations pertaining to the watershed. Rules and regulations should be posted on all watershed boundaries.

Agricultural Problems

Recommendations of the Federal Soil Conservation Service should be strictly followed, in order to prevent erosion of farm lands and the resulting turbidity and siltation of the receiving waters. Return flows from irrigation have in several instances created problems of turbidity, sedimentation, and increased chemical content which affect water quality and bacterial pollution. The first requirements are to use all of the water applied and to control the rate of flow to reduce erosion through more efficient irrigation. Further study is needed before recommendations for the full solution to the problem can be made.

Sawmill Operations

Sawmills located in close proximity to any waterway should take the following precautions in the disposal of waste sawdust, bark, slabs, and trimmings:

1. At the mill site, wastes should be kept above the high water mark, and out of any adjacent waterway in a place where they will not be washed into the water later.
2. If debris is to be burned, a properly constructed burner must be used. The burner should be located far enough away from the water so that unburned waste will not escape into the water way either on the ground or through the air.
3. Chutes which cross a waterway should be constructed in such a manner that the wastes will not fall from the chute to the waterway.
4. Burned-out screens and sections should be patched or repaired immediately.
5. Chutes carrying wastes to a burner under forced draft should be deflected downward, or should be passed through a hopper or a series of baffles, so that the fine sawdust will tend to settle to the fire and will not be carried out the screen.
6. Sawmills which truck sawdust and slabs away from the mill site should have these wastes dumped away from waterways, and in no case should sawdust and slabs be dumped below the high water mark of the waterway, or in such a position that they will later wash or leach into the waterway.

When log ponds are located near watercourses, they should be so located that only a portion of the stream flows through the pond. The overflow should be regulated in such a way that the amount of sawdust, chips and suspended matter that reaches the waterway is reduced to a minimum. Log ponds should be cleaned by dragging or dredging, rather than by flushing into a stream or river.

Summary

The increasing demand for water of high quality to supply municipal and industrial needs is directing attention to activities within the watersheds from which these supplies are taken. Activities such as logging, road construction, farming, and recreation in watersheds can be so controlled as to give a significant degree of protection to the waters. Suggestions have been made for such control programs.

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Maintaining Wells by Chemical Cleaning*

by GORDON L. E. LINN

Mgr., Duhernal Water System, Parlin, N.J.

THE Duhernal Water System, organized in 1939, operates 20 gravel-packed wells varying in productivity from 350 to 2,000 gpm. Eighteen of the wells, in Old Bridge Sand, are 80-100 ft deep, and two wells, in Farrington Sand, are about 300 ft deep. Both water-bearing sands are members of the Raritan formation of the Upper Cretaceous Age. The well field is located near an artificial lake on the headwaters of the South River in New Jersey. The present firm capacity of the system is 16 mgd, with frequent hourly peaks of 20 mgd. In order to meet the water demand, the cleaning of wells and connecting pipelines becomes an important routine job.

The two wells in Farrington Sand produce as much water now as when drilled and do not require any cleaning. Owing to a serious salt water intrusion problem, however, they are operated only when absolutely necessary. Two of the wells in Old Bridge Sand were recently placed in service and do not yet need cleaning. Another has been operating almost continuously for 14 years, and was cleaned only once, in January 1952, when the pump was reconditioned. The productivity at that time was increased only 19 gpm (from 456 to 475 gpm). This well and another installed in 1947 maintain almost constant production, varying only slightly with the ground water level. They are not contaminated by any bacteria and there are no large deposits in the pump, pump columns, or discharge lines. The other fourteen wells in Old Bridge Sand require periodic cleaning for reasonable productivity.

The cleaning program at Duhernal is conducted in three phases: (1) chemical cleaning of the sand stratum and gravel pack around the well screen; (2) chemical cleaning of the well screen, pump, and pump discharge column; and (3) mechanical cleaning of the connecting pipelines and the distribution system. The frequency with which any part of the well system is cleaned affects the overall productivity. A well in which the sand and the gravel pack are clean may be able to deliver more water than a pump fouled by bacterial growths or other deposits can handle. When the pump is clean and the sand stratum is clogged, the productivity will also be less than normal. Even if the well and pump are clean, fouled connecting pipelines will lower production owing to increased back pressure. Therefore, for a well to maintain reasonable production, it is necessary that all parts of the system be cleaned according to schedule. The rate of decrease in production determines the frequency of cleaning, which may vary from once a year for some wells to as often as once in 2 months or less for others. It is a disheartening fact that every part gets dirty again shortly after being cleaned.

Each of the Duhernal wells is equipped with flow and pressure meters, and the productivity is checked daily. Capacity tests of wells under standard pressure conditions are made periodically, to determine the need for cleaning and to measure the effectiveness of any cleaning program.

The eighteen Old Bridge Sand wells fall into three groups, according to their cleaning requirements. The well and pump cleaning program is outlined in Table 1 and described in detail below. Group *C* wells do not require cleaning, all decreases in production being traceable to lowered ground waters levels or pump wear.

Sand and Gravel Cleaning

It is believed that the principal plugging material in the sand strata and the gravel pack around the wells in Group *A* is clay, a common situation in shallow wells along the Atlantic seaboard. As the sands are about 40,000,000 years old, it may be wondered why the sand did not become plugged with clay during the long period before pumping started. The answer to this question must be the reduced rate of

TABLE 1

Well and Pump Cleaning Program

Well No.	Chemicals Used*		Normal Interval Between Cleanings wk	Original Capacity gpm
	Sand	Pump		
Group A				
3	H_2SO_4, HCl, PO_4	H_2SO_4, HCl	26	656
4	H_2SO_4, PO_4	H_2SO_4	52	700
5	H_2SO_4, HCl, PO_4	H_2SO_4, HCl	10	567
6	H_2SO_4, HCl, PO_4	H_2SO_4, HCl	10	630
14	H_2SO_4, HCl, PO_4	H_2SO_4, HCl	10	880
15	H_2SO_4, PO_4	H_2SO_4	10	725
16	H_2SO_4, PO_4	H_2SO_4	20	730
Group B				
1	H_2SO_4	H_2SO_4	52	640
2	H_2SO_4	H_2SO_4	52	650
17	H_2SO_4	H_2SO_4	52	700
18	H_2SO_4, HCl	H_2SO_4, HCl	20	700
10	H_2SO_4	H_2SO_4	52	1,400
11	H_2SO_4	H_2SO_4	52	1,210
12	H_2SO_4	H_2SO_4	75	1,030
Group C				
8	no cleaning required			455
13				1,020
A.F.				1,350
B.F.				1,840

* H_2SO_4—inhibited sulfuric acid; normal amount used per well, 45 gal. HCl—inhibited hydrochloric acid; normal amount used per well, 90 gal. (The acids used are products of E. I. du Pont de Nemours & Co., Wilmington, Del.) PO_4—phosphate; normal amount used per well, 50-75 lb.

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movement of water through the sand. It is known that, at times, a well will produce clay-colored water at a high rate of pumpage and relatively clear water at a low rate.

Clays are in their most dehydrated form in an acid environment. This probably explains why, when some wells are treated with acid, there is no increase in production even though large quantities of deposits are removed. In general, wells drilled in rather clean sand do not plug readily.

The cleaning of the sand stratum around each well in Group *A* consists of deflocculating and dispersing the clay particles from the sand and gravel and subsequently removing them from the well by pumping to waste. On some wells, frequent cleaning with small doses of chemicals is more effective than fewer cleanings with larger doses. It is believed that much of the clay in the sand around a well is deposited by mechanical filtration, as ordinary backflushing or surging will frequently remove a large portion of this material. It is often stated that resting or rotation of wells tends to maintain or improve production by changing the flow pattern through the sand and perhaps releasing the deposits in the formation so that they are removed when the well is placed in service again.

The clogging of sand and gravel may also be due to the cementing action of iron deposits when the pumping level in the well is consistently below the top of the screen. Recent cleanings at Duhernal indicate that a combination of 25 lb of sodium hydrosulfite, a reducing agent, with 50 lb of tetrasodium pyrophosphate is more effective than phosphate alone. Occasionally, inhibited sulfuric and hydrochloric acid are also used, depending on the results of the phosphate cleaning and the color of the waste water.

The sand and gravel around the wells in Group *B* are cleaned with inhibited sulfuric or hydrochloric acid and sometimes phosphate. The cleaning of the sand strata of the wells in either group is the most tedious phase of the operation.

Screen and Pump Cleaning

The well screen, pump, pump discharge column, and connecting pipelines require periodic cleaning, mainly to remove bacterial growths. The type of bacteria most common at Duhernal is *Gallionella ferruginea*, or a similar organism, which feeds on ferrous iron and has a very rapid growth. For example, inside a pipeline, it will grow into a mass as thick as 1 in. in about 10 weeks. It will reach greater thickness on the long-radius side of an elbow than on the short-radius side, because more water—and, hence, more food—passes the former. This accumulation may be described as a soft, brick-red slime consisting of iron oxide and dead bacteria, held together by a matrix of live, threadlike organisms. The deposit is easily wiped off the pipe with the hand. A typical analysis of this deposit is given in Table 2.

TABLE 2
Slime Deposit Analysis

Item	Amount per cent
Fe, Al, P (as Fe_2O_3)	56.16
Total Fe (as Fe_2O_3)	48.31
Moisture (loss at 105°C)	8.79
Total loss on ignition (organic matter plus moisture)	27.60
Silica (as SiO_2)	10.17
Qualitative Tests	
Co_3, SO_4, Cl, Ca	no
PO_4, Mg	yes

The rippled surface of the deposits causes eddy currents on the periphery of the water passing through the pipe, so that the friction coefficient is lower than it would be for an equivalent thickness, of smooth-surfaced scale; hence the need for frequent pipeline cleaning. It is interesting to note that an adjacent well field at Runyon, N.J., is not troubled with bacterial growths. The water there is removed by suction and then lime treated and filtered to extract the iron. It is evident that the iron bacteria will not grow under a partial vacuum and, of course, will not live after the iron has been removed from the water and the pH raised.

The cleaning of the screen, pump, and pump column is usually accomplished with inhibited sulfuric acid, which dissolves the bacterial growths and, after 24 or 48 hr, may be pumped to waste. If the deposit is a hard scale, inhibited hydrochloric acid is used, and sometimes a mixture of both is employed, in order to take advantage of the heat generated. A small sample of the deposit placed in glass beakers with different acids readily shows which acid will dissolve or disperse it. Of course, it is possible to clean the screen, pump, and pump column mechanically, by removing the pump from the well, but such a method costs about $1,000, approximately ten times the price of chemical cleaning. Moreover, with mechanical cleaning, the well is out of service for a longer period than with chemical cleaning.

In addition to the two acids previously mentioned, the list of chemicals that have been used to clean Duhernal wells includes: sodium hexametaphosphate, adjusted to pH 8.0 with sodium silicate or sodium carbonate; a commercial mixture of hydrochloric acid, ammonium bifluoride, and a wetting agent; calcium chloride; chlorine; various synthetic detergents (used with phosphates); sodium hydrosulfite (used with phosphates); sodium tripolyphosphate; and tetrasodium pyrophosphate. The effectiveness of some of these chemicals has not been completely evaluated.

There appears to be no relationship between the chemical composition of the water and the need for cleaning the wells. It is suspected, however, that the necessity for cleaning the pumps and pipelines is affected by the total water pumped, because the more iron furnished the bacteria, the faster the growth. Table 3 shows the range in concentration of various chemicals in Old Bridge Sand well water during 1952.

TABLE 3
Well Water Analysis

Item	Range
pH	4.2-6.2
Phenolphthalein acidity—**ppm**	3.3-132
Methyl purple alkalinity—**ppm**	0-15
Sulfates—**ppm**	11-50
Iron—**ppm**	2.4-24
Hardness (soap test)—**ppm**	8.8-17

Chemical Cleaning Method

The wells have aboveground discharge lines with 2-in. nipples welded at the top for air release valves. The valve is replaced by a steel funnel through which the chemicals are poured into the discharge piping. The chemicals flow backward down the pump discharge column, through the pump, and into the well. The discharge check valves have bypass lines with stop valves. If the chemical is to be used for cleaning the sand, the bypass line valve is opened to waste and the discharge line backflushed. Then the waste valve is closed, and water from the system goes down the pump column and forces the chemicals out into the sand formation. The farther the sand to be cleaned is from the screen, the more backwash water is required.

After each treatment, the well capacity is tested under standard conditions of pressure and flow. When there is no more improvement in capacity or when it is back to normal, the treatments are stopped. Sometimes, even after frequent chemical treatments, the capacity of the well is less than at the start. It is then assumed that the formation has become plugged

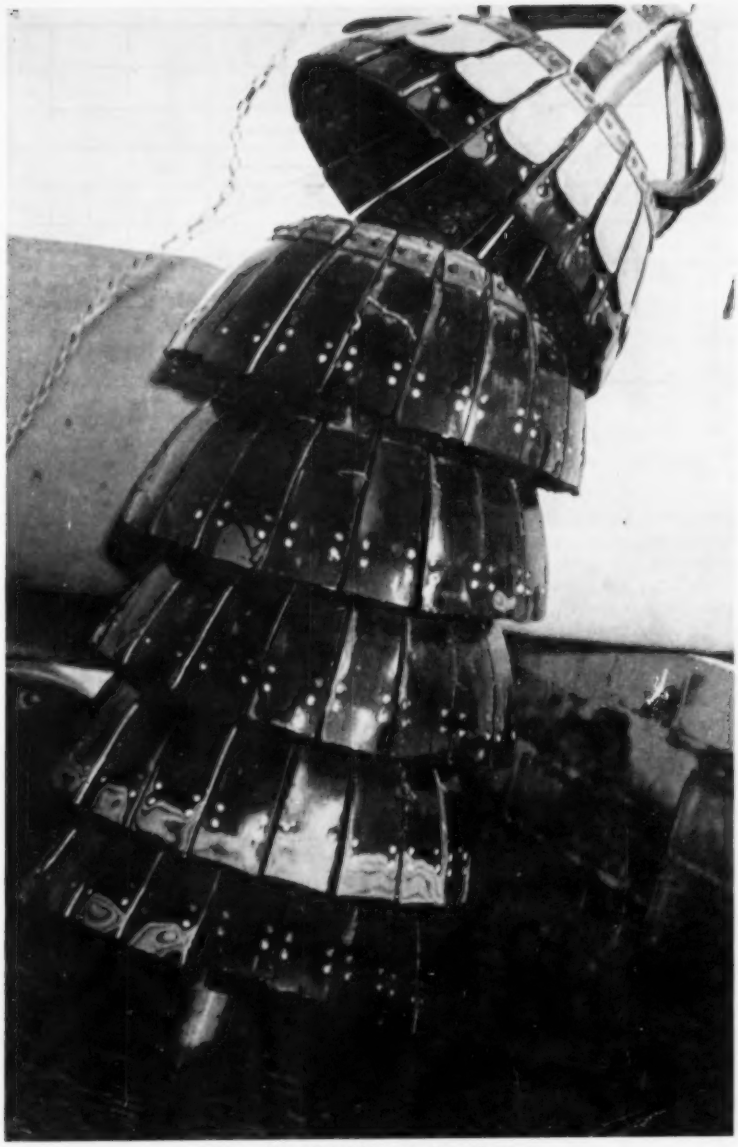

Fig. 1. MECHANICAL pipeline cleaner
The Duhernal - designed, rubber - covered arms of the cleaner wipe off the slime deposits with a squeegee action.

again near the screen.

In one instance, four 2¼-in. injection wells with 3-ft screens, at various depths in the sand stratum, were equally spaced about 10 ft from the center of a well to be cleaned. Various chemicals were poured into the injection wells and spread by pumping air and water. This method was abandoned because it was not found much more effective than treating the well from the inside through the screen. On another occasion, a pailful of sand and fine gravel was poured slowly down the inside casing of a well, while the pump was discharging to waste, in the hope that the deposits would be removed mechanically from the pump and pump column. The results were not sufficiently satisfactory to warrant taking a chance on cutting the pump impellers and bearings.

From the water level in observation wells sunk in the gravel pack and within 10 ft of the center of the producing well, it is possible to determine when the sand formation is plugged and how effective the chemical treatment is. When it is decided that the maximum amount of water is entering the well and that the sand stratum is clean, the pump is tested against its characteristic curve. If the pump and discharge column need cleaning, inhibited sulfuric acid is poured into the discharge piping in the manner previously described, but without any backwash water, so as to hold the acid in the pump. If this acid is not completely successful, inhibited hydrochloric acid is used, and sometimes a combination of both is employed.

Pipeline Cleaning

Pipelines fouled by bacterial growths are cleaned mechanically about every 10 weeks, the interval depending on the quantity of water passing through the lines. During high-flow periods, as in the summer, the amount of water and bacterial food is greater than in low-flow periods.

Chain-covered rubber ball cleaners are used on short lengths of 6–24-in. pipe. Some of the chains are covered with sections of rubber hose to protect the asbestos-cement pipe. Occasionally two ball cleaners are utilized, one with water and the other with air. The former insures the cleaning of the bottom of the pipe.

Two cleaning machines, one for 18-in. and one for 30-in. pipe, are also employed. They are made in sections, to permit going around an elbow, and the flat, rubber-covered pieces which move along the pipe are spring loaded. The squeegee action of the rubber-covered arms easily wipes off the deposit, while the driving water behind the cleaner flushes out the dirty water through blowoff connections located at low points along the line. Access boxes have been installed to allow the cleaners to be inserted in the mechanically coupled pipelines. The 18-in. cleaner travels approximately 14,000 ft, and the 30-in. cleaner 29,000 ft between access boxes. They do an excellent job, often raising the pipeline friction co-

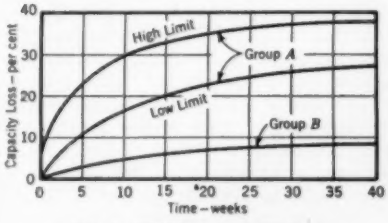

Fig. 2. RATE of capacity loss
The seven Group A wells are affected by clay and iron deposits. The seven Group B wells are affected by iron deposits only.

efficient to more than 140. A photograph of one of the cleaning machines is shown in Fig. 1.

Effects of Cleaning

Figure 2 shows that the average percentage loss in capacity of the seven Group *A* wells, affected by clay and iron deposits, falls between a low and a high limit. Ten weeks after cleaning there is a 16.5 per cent loss in the capacity of some of the wells and as much as 30 per cent in others. Twenty weeks after cleaning the low-limit loss is 22.5 per cent, and the high limit 35 per cent. The wells in Group *B*, affected only by iron deposits, do not fall off in capacity as much as those in Group *A*. For example, after 10 weeks, the average percentage loss is only 4.5 per cent, and after 20 weeks only 6.5 per cent. In addition, the variation between wells in Group *B* is not as great as in Group *A*.

Typical curves indicating the effect of a fouled pump and line on pump capacity are shown in Fig. 3. For example, when the pump and the discharge line are both clean, the pump will deliver 700 gpm. When both are dirty, the pump will deliver only 390 gpm. If the pump is clean and the pipeline dirty, 500 gpm will be delivered, and if the pump is dirty and the pipeline clean, 585 gpm.

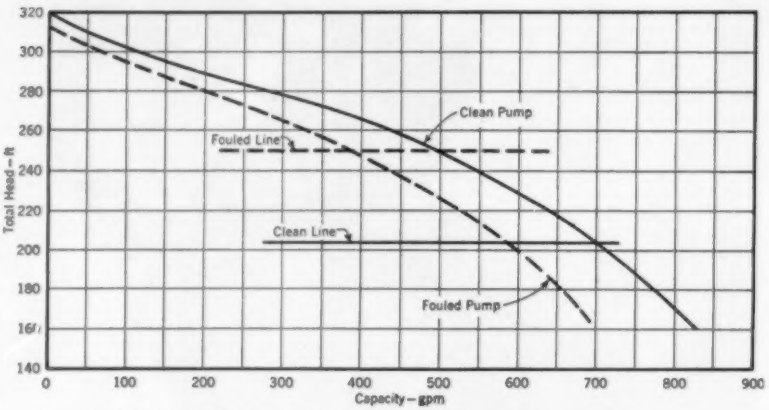

Fig. 3. EFFECT of fouled pump and line on pump capacity
A fouled pump and discharge line will suffer a capacity loss of more than 300 gpm.

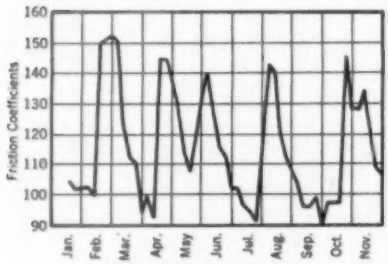

Fig. 4. VARIATIONS in friction coefficients
Peak readings were obtained within a week after mechanical cleaning.

Figure 4 shows the weekly variations in friction coefficients on a typical section of distribution pipeline. The peak readings were obtained within a week after mechanical cleaning. The coefficients fall off rapidly shortly after cleaning, dropping from a high of approximately 150 to a low of approximately 95.

Conclusion

Chemical cleaning at Duhernal is still in more or less of an experimental stage, although it has been practiced for about 10 years. Tests with different kinds of chemicals are being conducted regularly, using various methods and quantities. Experience has shown that there is no easy cleaning method and that no treatment of any type is successful in improving production every time. Well cleaning demands a relatively high level of supervision, ingenuity, and patience to get the best results. Frequently a well requires several treatments before any improvement is noted, although, on occasion, one treatment may give the maximum improvement possible.

Without any cleaning, at Duhernal, it would be necessary to install six new wells and 10 miles of duplicate pipelines, at a cost of perhaps $1,000,000. Chemical and mechanical cleaning, therefore, is not only economical and practical but necessary to maintain reasonable well productivity.

An Adequate Distribution System

by N. T. VEATCH

Cons. Engr., Black and Veatch, Kansas City, Mo.

THE DISTRIBUTION system is the marketing facility of the water utility. It represents some two-thirds of the investment in water works plant of the average community. To provide fully adequate and satisfactory service to the customer requires that the mains making up the system be large enough to deliver water to all users in quantities sufficient to meet their requirements and at adequate pressures.

Water Usage

The customer rate of water use varies over a wide range from city to city. Results of a survey of water works operating data for 1950, made by the American Water Works Association, indicate that for the 387 cities covered, water production varied from a minimum of 51 to a maximum of 446 gallons per capita per day, with a mean of 138 gpcd. The mean sales figure for these cities was 110 gpcd.

These average daily figures, although generally useful, are not necessarily valid for any specific city. Evaluation of the adequacy of a distribution system requires the determination of the probable maximum hourly rate of delivery for the specific system under investigation. If this information cannot be obtained from operating records, it can be developed from detailed analyses of customer usage throughout the system. Use of generally accepted ratios in computing system-wide maximum short-period demands from annual average daily demands may give erroneous results when applied to a specific system.

In estimating future maximum rates of water consumption, recent upward trends in the customer rate of use should be recognized. In the period 1945-1950 the average annual customer use rate increased approximately 10 per cent; in many cities, particularly where air conditioning is extensively used, the increase was even greater.

The domestic customer use rate has been increased by the greatly increased use of water for lawn sprinkling, by the rapidly expanding use of household garbage grinding devices, and by the use of air conditioning equipment in areas where summers are hot and dry. Continuation of this upward trend can be expected as long as the general economic status of the populace remains at a high level.

The commercial customer use rate has been greatly increased by the use of air conditioning equipment. Although many such installations are not provided with water-conserving equipment, therefore, limitations of water supply and distribution facilities have prompted many cities to require the inclusion of water-conserving equipment in all new installations having a rated capacity of more than two tons.

Recent studies of prospective future peak demands on the water distribution system at Kansas City, Missouri, indicate that the peak day water requirement, exclusive of air conditioning demands, in 1970, will be 184 mgd, while the peak day total requirement, including air conditioning use, in that year, will be 308 mgd. Thus, the operation of air conditioning equipment, even though a large percentage of it is of a water-conserving type, will increase the peak day customer demand by 67 per cent.

Fire Flow Requirements

Fire flow requirements must be considered, in evaluating the adequacy of a distribution system, since they are imposed on the peak day customer demand. Although the quantity actually used for fire fighting over a yearly period is small in relation to the total customer use, the rate of use during the period of a serious fire is large.

The formula used by the National Board of Fire Underwriters for determining the probable maximum fire demand rate in the high-value area of cities up to 200,000 population relates this peak rate to the population of the city. The results obtained by application of this formula have been widely accepted by engineers and used as a basis for the design of water distribution systems to serve such high-value areas.

The maximum demand on a distribution system during a fire is usually taken as the average customer use on the maximum day plus the fire demand as calculated by means of the Underwriters' formula. For cities of more than 200,000 population, the maximum fire-flow demand is taken as 12,000 gpm, for a single fire in the high-value area, with an additional demand of 2,000 to 8,000 gpm for a simultaneous fire outside this area.

Adequate Pressures

To be considered adequate, pressures in a distribution system must be 25 to 40 psi in residential districts containing dwellings up to four stories in height, and 75 psi in commercial districts. The American Water Works Association recommends normal static pressures of 60 to 75 psi as sufficient to supply normal uses in buildings up to ten stories in height, effective sprinkler system service in buildings up to five stories high, direct hydrant service for a minimum number of fire hose streams, and to allow some margin for local pressure fluctuations caused by sudden heavy drafts on the system.

Distribution Storage

The proper functioning of a water distribution system is materially facilitated by the use of water storage structures, reservoirs, stand pipes, and elevated tanks. Such storage, if at the pressure plane of the service area, can be used to equalize pumping rates at the supply works; a practice which permits the use of more economical main sizes and results in minimum pumping costs.

Also, such storage constitutes a reserve supply which can be delivered into the system without further pump-

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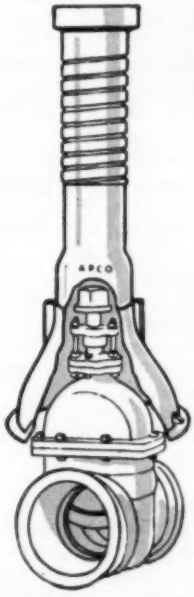

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ing to meet heavy demands for fire fighting or the normal demands while emergency repairs are made in the system or supply works.

Ideally, the quantity of water stored at the pressure plane should be at least equivalent to the sum of the maximum day requirement for customer use and the required fire-flow for a period of ten hours, less the *firm* daily capacity of the system supply works; preferably it should be, say, 10 per cent in excess of this quantity. Determination of the quantity of storage required in any specific system requires detailed study of its demand and supply characteristics, and of available locations for such storage.

Generally the most effective location for distribution storage, when considered as a supplemental supply source, is along the perimeter of the high-consumption district at a point diametrically opposite from the high-service pumping station at the supply works. With the storage structure at such a location, head losses within the high-consumption district will be minimum, and the quantity of water which can be delivered to points within this district at suitable pressure will be maximum. If the storage structure were located at the high service pumping station, or at a point between this station and the high-consumption district, the water plane in the district at times of heavy demands would be much lower than in the former case, and the quality of service much less satisfactory. In practice, the selection of a storage structure site is not uncommonly based on considerations of availability and aesthetics rather than on sound engineering principles.

Gate Valves

From the viewpoint of distribution system operating personnel, one of the most useful items of equipment —and in some systems one of the scarcest—is the gate valve. The purpose of valves in a distribution system is to provide the means for isolating a short section of main to permit the making of repairs, often of an emergency nature, without interrupting service to more than a minimum number of customers. The National Board of Fire Underwriters recommends that gate valves be installed at such locations and spacings that "no single case of accident, breakage or repair to the pipe system, exclusive of arteries, will necessitate the shutting from service a length of pipe greater than 500 feet in high-value districts or greater than 800 feet in other sections, and will not result in shutting down an artery."

Each functionally important gate valve, such as those at each side of a stream crossing, and each gate valve 12 inch and larger in size, will justify being housed in a concrete or masonry vault, which should be large enough to provide adequate space for personnel and tools required for the operation and maintenance of the valve.

Accurate and permanent records of the locations of all valves in the system should be readily available to all operating and maintenance personnel. Such records should include complete information as to make, type, size, direction of turning to open, location, type of installation, method of operation, etc. Good records, readily available, often prove of great value in emergency situations.

Hydrants

The distribution system should be equipped with an adequate number of hydrants so located and spaced as to provide fire protection for the entire service area. Hydrants predominately in use on water systems in the United States are of the dry-barrel type and are usually equipped with two hose outlets and one pumper outlet. A number of systems have installed hydrants equipped with two pumper outlets and no hose outlets in their high-value districts.

The distribution or spacing of hydrants depends on the maximum fire flow requirement for the district under consideration. In residential areas, in which block lengths are not over 500 feet, a hydrant should be located at each street intersection. In blocks longer than 500 feet, a hydrant should be placed midway between as well as at the intersections.

In areas occupied by large apartment houses, and in mercantile and industrial districts, it may be necessary to install two, three, or even four hydrants at the intersections, as well as one or more at locations between intersections, in order to deliver the maximum fire flow requirement.

The policy of limiting the minimum size of hydrant supply branches to 6-inch and of installing gate valves in all hydrant branches, which has been adopted by many water utilities, is believed to be sound.

Maintenance of Valves and Hydrants

Continuous preventive maintenance of distribution system valves and hydrants is a "must" if these important adjuncts are to be ready to serve their appointed function at all times. Each valve and each hydrant should be carefully and thoroughly inspected and operated through a complete cycle at frequent intervals by trained personnel. The frequency of such periodic inspections varies in different systems, but generally such inspections are made yearly.

Since damage to hydrants from external forces generally occurs more frequently in the spring and summer seasons, due to street construction and repair activities and traffic mishaps, the hydrant inspection program should be accomplished during the fall. The discovery and correction of faults in the operation of hydrant barrel drains is particularly timely at this season.

Minor maintenance work, which can well be performed in connection with the hydrant inspection operation, should include lubrication of the operating nut, greasing nozzle cap threads, caulking loose nozzles, and tightening or replacing stuffing box gland packing. The addition of leak and pressure tests to the program will increase the time required for its completion possibly 20 to 25 per cent.

The valve inspection and maintenance program can be carried on at any time, although with less efficiency when streets are covered with snow. The use of power-driven valve operating equipment, preferably of the truck-mounted type powered by a takeoff from the truck engine, will greatly facilitate and speed up the progress of the program.

Maintenance work which can be performed by the inspection crew on buried valves is limited to cleaning out valve boxes and adjusting their height. Such work on valves in vaults will include tightening or replacing stuffing box packing, and cleaning and lubricating valve operating gears.

Meters

Meters, both customer and those used for totalizing pumpage, etc., are a very essential part of any distribution system. No attempt is made here to discuss details of these meters. It is desired, however, to emphasize their value and importance in reducing waste in customer usage and in providing data which enable proper checks to be made of the efficiency of the distribution system. In addition to meters, pressure gauges of suitable design and number are an essential feature of a well-operated system.

The much-discussed question of the use of meters on private fire protection services as a means of reducing unaccounted-for water, dis-

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couraging the still not infrequent attempt to steal water through such services, and, in some instances, to control maximum demands for legitimate uses, seems to be as far from a generally acceptable answer as ever. The literature of the industry is replete with accounts of the discovering of unauthorized connections to private fire lines, through which great quantities of water were being taken without compensation to the utility.

In recent years fire service type meters have been designed which will accurately measure all flows and which, since they impose practically no obstruction to full flow through the service line, satisfy all the requirements of the National Fire Protection Association.* With such meters available, it is somewhat difficult to understand the failure of water works management generally to adopt a policy requiring the installation of such equipment on all private fire services.

Many water utility operators, the owners of properties having private fire services, and the fire underwriters generally, oppose the use of fire flow meters on the premise that the additional revenue to the utility resulting from their use would not be sufficient to offset the cost of providing and maintaining the metering installations; that frequent inspections by water utility, public fire department, and underwriters' personnel will discover conditions under which the use of water for purposes other than fire-fighting or testing may or does occur.

The utility operators who favor metering all private fire lines contend that the reduction in operating costs resulting from the decrease in "free" or "lost" water effected by metering more than offsets the costs to the utility for operating and maintaining such metering installations, it being the general practice of these utilities to collect the cost of the meter installation from the customer. They consider, also, that even though unauthorized uses of water are detected by metering and such uses are discontinued, the very existence of the meters can be credited as making available for legitimate uses, at low cost, considerable system capacity previously committed to non-revenue-producing functions.

It is almost universally the policy of water utilities, both public and private, to furnish water for fire-fighting uses without charge, whether through public fire hydrants or through private fire lines. It is not the wish or intention of proponents of private fire line metering to change the status quo in this respect. With this position the author is in complete agreement.

* N.F.P.A. Handbook of Fire Protection, 10th Edition, p. 814.

Service Building

The successful operation of a water distribution system requires unfailing maintenance of all of its parts. Meters must be inspected, tested, cleaned, and overhauled at frequent intervals to restore their accuracy of measurement. Valves and hydrants damaged in service, or which have become inoperative for any reason, must be repaired. Many distribution departments find it more economical and satisfactory to maintain automotive and heavy construction equipment in their own shops than to depend on commercial shops for this service. Department supplies must be adequately stored and properly accounted for to prevent loss and damage.

In the past, these activities all too frequently have been housed in wholly unsuitable structures, such as abandoned fire, police or pumping stations, dismantled steam boiler plants, etc. More recently, however, water works management, in general, has come to recognize the necessity of providing adequate housing and facilities for the distribution maintenance operations. Many smaller systems, serving as few as 5,000 customers, will be found to have well-designed and equipped service buildings. Larger systems may have several such buildings, each serving a specific district or part of the system.

Local conditions and requirements will control the location, dimensions, equipment and architectural treatment for a specific service building. The influence of these criteria can best be explained by describing briefly such an installation recently completed to meet the needs of a distribution system serving approximately 40,000 customers in a South Atlantic state.

The utility constructs all distribution and feeder mains 16 inches and smaller with its own forces and equipment, and operates 18 automotive vehicles. The service building, equipment shed, and pipe yard occupy a fenced 4-acre site located at the geographical center of the distribution system and served by a railroad spur and a paved street. The maintenance building, a one-story brick masonry structure with concrete floor and roof slabs, has a gross floor area of 8,540 square feet. Allotment of net floor space within the building is:

Use	Area, Sq. Ft.
Meter Shop	1,250
Automotive Shop	3,200
Small Stores	750
Large Stores	850
Wash Rooms and Lounges	1,450
Office	400
Lobby and Corridors	500
Total	8,400

Exterior wall surfaces are of face brick, with wall copings and window sills of cut stone. Interior wall surfaces in the lobby, corridors, meter shop, lounges and washrooms are of glazed tile; those in the offices are plastered and painted and all others are of common brick.

Floor surfaces in the lobby and offices are of quarry tile; those in the lounges and washrooms are of ceramic tile; those in the meter shop, stores rooms and corridors are of cement mortar topping, and all others are of monolithic troweled finish. Ceilings, which are the exposed under side of the roof slab, are painted. Ceiling height is 10.5 feet throughout the building except in the automotive shop, where it is 15.67 feet.

Illumination for the offices, meter shop, small stores room and lounges is by fluorescent light fixtures; in all other parts of the building it is by single-lamp incandescent light fixtures. Heating is provided by a two-pipe, forced circulation, hot water system.

Service Building Equipment

The principal items of equipment are:

Meter Shop: Sand blast cleaning equipment; acid bath sinks with blower-equipped fume hood; two meter testing assemblies with calibrated tanks; two work benches; a 35-foot work table; desk and file cabinet, and meter storage racks. Compressed air is piped to outlets on the work benches and table.

Automotive Shop: Air compressor and receiver; oil-operated single-post automotive hoist; 50-foot work bench; 2-ton, chain-operated monorail hoist. Compressed air and electrical outlets are located along the work bench.

Each Washroom: A 54-inch, foot controlled, stainless steel wash fountian; 3 water closets; 3 urinals; 2 shower stalls; water heater; 20 steel lockers; two 8-foot benches.

Large Stores Room: Chain-operated, 1½ ton, monorail hoist.

Yard Facilities

The maintenance building yard is paved for a distance of 140 feet with asphalt penetrated crushed stone. In this paved area is an automotive fuel service station, with pumps and un-

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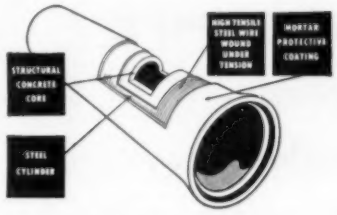

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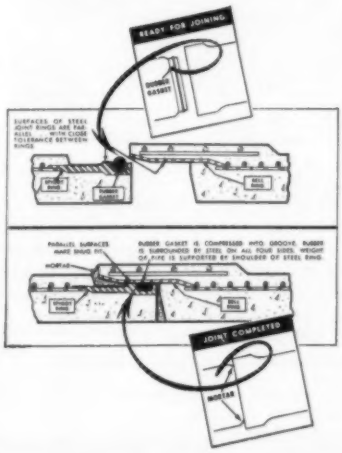

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GALLONS OF WATER DELIVERED

INITIAL RATE OF FLOW—With Prestressed Pipe, water flows over concrete, which equals the highest flow coefficient of *any* pressure pipe structural material.

LONG TERM RATE OF FLOW—Concrete not only retains its high "C" value, it often increases because of a slippery surface that forms on the concrete. Tests in Louisville show an increase from a "C" of 145 in 1931 to a "C" of 149 in 1948. Tests in Denver show an increase from 141 in 1925 to 150 in 1943.

TUBERCULATION AND CORROSION—Under ordinary circumstances Price Pipe will never corrode or tuberculate. After years of service, it will have exactly the same diameter and be just as smooth as when installed.*

JOINTS—The rubber and zinc-coated steel joint on Price Pipe is *flexible*. It can adjust to expansion, contraction, vibrations and settling without leaking even with high internal pressures.

MAINTENANCE

CLEAN OUT—Price Pipe will neither tuberculate or corrode, and will require no cleaning out.

RELINING—The structural concrete core of Price Pipe serves as its lining. It is held in compression by the wrapping of high tensile steel wire and is an integral part of the pipe. It does not chip or disintegrate. Relining is never required.

BLOW UPS—Blow ups and resulting floods are all but impossible with Price Pipe. Its design makes it shatterproof.

TAPPING — Any water-works serviceman can tap Price Pipe, under pressure, using regular type, long travel tapping machine, with a carboloy tipped cutter. The design of the tap actually makes the pipe *stronger* at the point of the tap.

COST

ORIGINAL COST—Price Pipe, in spite of its long life, sustained capacity and great strength costs no more than other types of water pipe. Under certain conditions it may even be considerably less.

INSTALLATION — On most installations a back hoe both digs the trench and lays Price Pipe, resulting in speed and low cost. This is because of the self-centering joint on which steel takes the backload and rubber forms the seal. Contractors generally bid lower on the installation of Price Pipe than any other type of water pipe.

PUMPING COSTS — Price Pipe's flow coefficient *stays* high and the bore stays smooth. Pumping costs do not rise as they do with some pipes.

LONG TERM COST — Here's where Prestressed Pipe really shines. Add to low original cost the advantages of no cleanouts, no relining, no blow ups, absolute minimum leakage, and lower pumping costs, plus the permanency of concrete . . . then you have *true* economy.

YOUR REQUIREMENTS

PRESSURES—Prestressed Pipe can be designed for any pressure common to American waterworks practice with adequate reserve strength for normal overloadings.

SPECIALS — Connections and fittings are readily available. They are manufactured of reinforced concrete and custom tailored to the design requirements.

SIZES—Prestressed Pipe is available in 16-foot lengths and in diameters of 16″, 20″, 24″, 30″, 36″, 42″, 48″ and larger.

DELIVERY — Price Pipe is available from plants in Dayton, Ohio, and Miami, Fla. On large jobs a portable plant can be set up on the job site.

OTHER TYPES OF CONCRETE PIPE—Price Brothers Co. also manufactures Concrete Steel Cylinder Pipe, Not Prestressed; Subaqueous, Sewer and Culvert Pipe.

INFORMATION — Price Brothers engineers know pipe line problems. They will be glad to help in any way they can, without obligation. For booklets on Manufacture, Laying and Tapping, write Price Brothers Co., P. O. Box 825, Dayton 1, Ohio. For general information mail the Reader Service Card.

*In isolated instances, but not common in America; algae and sponge formations will collect on the inside of all types of water lines. Rare soil conditions may affect the permanence of *any* pipe material.

Johns-Manville

Manufacturers of "Transite" Pressure Pipe

22 EAST 40th STREET NEW YORK 16, N. Y.

OFFICES IN ALL LARGE CITIES

Here's How TRANSITE PRESSURE PIPE with the Ring-Tite Coupling *Meets These 7 Basic Water Line Problems . . .*

IF YOU are faced with some—or all—of these 7 common water-line problems, here is information about Johns-Manville Transite® Pressure Pipe that may be of help to you...facts that tell how this modern asbestos-cement pipe is helping to solve these problems in many communities.

1. Handling costs:

Because it is light in weight and easy to handle, Transite Pressure Pipe keeps handling costs down. Loading, unloading, and all other subsequent handling operations are simplified. More footage can be hauled per truckload—reducing trucking costs—and distribution along the trench is easier and more quickly accomplished. Moreover, mechanical handling equipment is not necessary except where larger sizes are being used; the pipe sections are easily lowered into the trench with rope slings.

2. Installation costs:

Transite Pressure Pipe's light weight, easy handling and fast, accurate Ring-Tite® Coupling simplify assembly and save time every step of the way. It may be installed even under difficult weather, temperature and terrain conditions. The laying crew can install the pipe as fast as the trench is opened. This means less time on the job, appreciably lower costs. Only a few quick, sure steps are required to connect pipe with the Ring-Tite Coupling with the assurance of tight yet always flexible joints.

3. Soil corrosion:

Two factors give Transite Pressure Pipe exceptional resistance to corrosion: (1) the corrosion-resistant materials of which it is made; (2) the especially developed Johns-Manville process of manufacture which imparts a high degree of chemical stability to the finished pipe. This high resistance to corrosion has been substantiated by numerous installations. Many of these are serving as replacements in soils so destructive that the useful life of the pipe materials previously used had been seriously curtailed.

4. Internal corrosion:

Transite Pipe, because of its asbestos-cement composition, is not affected by tuberculation. Therefore, it is not necessary to resort to pipe of larger diameter to offset the internal effects of this costly form of pipe corrosion. And because progressive reduction of delivery due to tuberculation capacity is never a problem in a Transite pipe line, pressures and flows remain high—pumps operate at higher efficiencies. These factors are often reflected in better service and lower water rates in communities served by Transite lines.

5. Underground water losses:

The Transite Ring-Tite method of assembly gives to municipal water systems the ultimate in locked-in tightness and a completed pipe line that assures the utmost in full, free flow of water under pressure. With the Ring-Tite Coupling, rubber rings are simply, speedily "smoothed" into grooves in the Transite sleeve. This simple act "spots" them easily and accurately in exact position, ready for assembly, and once in the groove, they're there to stay. The Ring-Tite Coupling is designed to stop automatically in the correct position to form a tight yet flexible seal.

6. Vibration and stresses:

Not only is the Ring-Tite Coupling designed to stop in the correct position for tightness; it also stops in just the right position for separation of pipe ends within the joint. This means that the coupling automatically provides for expansion, possesses the flexibility to relieve line stresses in service. The flexible joints effectively absorb the vibration of heavy traffic, especially important where pipe is laid under busy highways or near railroad and street car tracks. Deflections up to 5° at each joint permit laying pipe around curves without special fittings.

7. Maintenance:

In thousands of communities, Transite Pipe—with its advantages of joints that remain tight and flexible, its corrosion resistance, and immunity to tuberculation—provides low-cost water transportation that requires little, if any, maintenance. Transite lines do not have to be cleaned, lined, or replaced because tuberculation has reduced their original capacity. Reports from communities all over the country prove that Transite's asbestos-cement structure provides economies that continue through the years.

Plus

. . . the advantages of a complete, nationwide TRANSITE PIPE ORGANIZATION. The facilities of this organization include more than 250 field representatives with headquarters in 58 cities. It also comprises a staff of competent installation instructors who explain recommended installation practices to pipe-laying crews.

This J-M service is an important factor in helping to assure the installation economies as well as the long-term *overall* economies that go with Transite Pressure Pipe. The work of this field organization is a vital part of the helpful Transite Pipe service which J-M offers the water works industry.

DIMENSIONS AND APPROXIMATE WEIGHTS OF TRANSITE PRESSURE PIPE

Transite Pressure Pipe is available in seven sizes from 4" through 16" and in three working classes—100, 150 and 200.

Class (maximum recommended working pressure, psi)	Equivalent head, feet of water	Nominal inside diameter, in.						
		4	6	8	10	12	14	16
		Pounds per linear foot including Ring-Tite Coupling						
100	231	6.3	10.6	15.8	21.8	29.7	38.9	48.8
150	346	7.6	13.0	19.9	32.0	43.8	58.5	73.0
200	462	9.3	15.4	23.9	37.2	51.7	69.0	89.2

derground storage tanks for gasoline, kerosene and diesel fuel. The equipment parking shed, a brick masonry structure 84 feet by 21 feet in plan with concrete roof and columns and clear headroom of 10 feet, is located along the rear of the paved yard area. This shed provides storage space for eight pieces of equipment.

The pipe storage yard, a graded area roughly 500 feet by 200 feet in dimensions, adjoins the maintenance building paved yard. Three parallel crushed stone driveways extend longitudinally through the pipe yard area.

Planned Layout

Meters brought in for testing and overhaul are unloaded onto a small concrete loading dock at truck-bed level, where they may be washed with a hose before being taken into the meter shop. Materials and supplies to be handled in the small and large stores rooms are unloaded onto a roofed concrete dock, also at truck-bed level, extending the full length of the exterior wall of these rooms.

The cost of this project, exclusive of site acquisition and fencing, was approximately $170,000.

Careful planning to meet functional requirements is apparent throughout this installation. Consideration of employee comfort and welfare is exemplified by the provision of modern and adequate wash and lounge rooms. The results are evident in improved efficiency of operations, as well as in high morale.

Water Main Extension Policy

Throughout the history of the industry water utility management has been faced with demands for water main extensions to serve new customers. Such demands have varied in importance from the opening of a single block of street in a well-gridironed system, to the development of large suburban subdivisions evolving into communities containing hundreds or even thousands of dwelling units.

How to finance such extensions is perhaps one of the oldest and most difficult of the unsolved problems confronting the industry. In addition to financing, the problem often involves factors relating to legal requirements and limitations; the implied or asserted obligation of the utility to provide water service throughout its primary service area and in areas contiguous thereto; limitations of capacity in the utility's existing production works and distribution system, and the possible effects of the development of suburban communities upon the status of existing residential and commercial districts within the parent city, as well as upon the plans of the parent city relating to annexation of these areas in connection with future orderly enlargement of the city.

It is perhaps quite generally thought that a water utility, either public or private, is obligated to extend its service to any area within the corporate limits of the municipality it serves, although it is recognized that the utility should not be expected to finance such extensions unless the anticipated net operating revenues resulting therefrom will be sufficient to amortize the required investment.

As to the question of extending water service into fringe areas outside the boundaries of the parent city; it is not likely that a utility is definitely obligated to serve such areas in the first instance, although in some states (Pennsylvania and Massachusetts among others) it may be obligated to expand its suburban service if it has already extended service beyond its boundaries. Whether or not a privately owned utility can be required to extend its service into suburban areas depends upon local laws, its charter or franchise provisions, state regulatory commission requirements, established precedents, and other local circumstances. To require such a utility to so extend its service, if the revenues to be derived from the extension would not be sufficient to support the necessary investment, would amount to confiscation of its property.

There is wide diversity in the practices and policies of water utilities regarding the making of water main extensions. The American Water Works Association, through the activity of its committee on Water Main Extension Policy, has been studying the legal, financial and civic aspects of the problem. The final report of this committee, yet to be published, will, it is hoped, serve as a guide to utility management in establishing procedures for administering main extension programs. A committee of the National Association of Railroad and Utility Commissioners is engaged in developing a set of uniform rules applicable to the operation of water utilities, which will include a recommended standard practice in relation to main extensions, and which will be recommended by that Association for adoption by state regulatory bodies.

System Check-Ups

The foregoing discussion has been limited generally to physical parts of the distribution. But system check-ups constitute a very important item in connection with operation. Constant study should be given to the matter of maintaining adequate pressures throughout the system, and this in turn directly concerns the matter of adequate main capacities. Therefore, system surveys to determine pipe capacities, operating pressures, etc., are essential to proper operating.

These surveys are usually made with the pitometer. The data obtained disclose the hydraulic properties of the mains (i.e., friction coefficients, etc.), as well as leakage. In large systems such surveys are generally carried on more or less continuously. In smaller cities they can be made less frequently. Between such surveys, constant attention should be given to such items as pressures, lost and unaccounted for water, incrustation of pipe, etc.

Distribution System Costs

The term "cost," as related to a fully adequate and satisfactory distribution system, can be discussed only in broad generalities. It may be considered from the viewpoint of the total capital investment, or the historical cost, or from the viewpoint of the cost of reproducing an existing system at present day prices.

On the historical cost, or invested capital basis, Howson* in a 1946 study of statistics on 100 water works systems found that the average per customer investment in water works plant had increased from $238 in 1925 to $310 in 1945. These 100 systems served 1,500,000 customers in the earlier year and more than 1,900,000 customers in 1946. If, on the average, the investment in distribution system were taken as two-thirds of the total plant investment, the per customer investment in distribution facilities would be $159 for 1925 and $207 for 1945.

Analysis of data presented in a report of the American Water Works Association indicates that in 1950 the mean book value per customer account, undepreciated, or the invested capital in water works plant, per customer account, varied by population groups from $254 for the smaller cities to $504 for cities over 500,000 population. Results of this analysis are given in Table 1.

Again, if the book value of distribution system facilities is taken as two-thirds of the total plant investment, the mean 1950 book value per customer account for these facilities by population groups was:

* AWWA Journal, Vol. 38, pp. 739-749.

Group	Mean Book Value per Customer Acct.	
	Total Plant	Distribution Facilities
1	$254.14	$169.44
2	273.35	182.24
3	295.26	196.85
4	311.32	207.56
5	409.78	273.20
6	503.93	335.97

†Survey of Operating Data for Water Works in 1950, AWWA Journal, June 1953.

A study of nine recent appraisals of water distribution properties indicates per customer costs, based on present construction prices, ranging from $240.56 to $507.06, the weighted average being $348.66. The cost of reproduction new for each of these properties was determined by applying construction prices current at each location on July 1, 1954, to actual inventories.

Although these figures indicate the costs of specific distribution systems at present day prices, and although they may serve to establish limits between which the actual cost per customer for any distribution system may fall, the characteristics of distribution systems are so diverse that average cost units derived from a study of any one such system cannot be applied with assurance to any other system.

TABLE 1
Capital Investment in Water Works Plant

Group	Population Range, 1,000's	No. of Plants	Total Pop. Served, 1,000's	Customer Accounts, 1,000's	Av. Persons per Account	Mean Book Value	
						Per Capita*	Per Customer
1	10 to 25	124	2,109	548	3.85	$66.01	$254.14
2	25 to 50	96	3,434	825	4.16	65.71	273.35
3	50 to 100	57	3,861	873	4.42	66.80	295.26
4	100 to 250	44	6,851	1,445	4.74	65.68	311.32
5	250 to 500	27	9,515	1,982	4.80	85.37	409.78
6	Over 500	18	25,398	3,724	6.82	73.89	503.93

*From Table 25, AWWA Journal, Vol. 45, p. 1330.

A fully adequate and satisfactory water distribution system is a rarity. Changing developments in land usage within or contiguous to the primary service area and the continuing upward trend in the use of water by the public, impose ever-increasing demands on the capacity of the system. Distribution facilities which a decade ago may have been considered as substantially adequate and satisfactory may in some respects be wholly inadequate to meet today's demands. Continual improvement of the system, by the installation of additional feeder mains, distribution storage, distribution pumping stations, and appurtenant facilities is necessary to maintain its adequacy.

Alert management will, by constant analysis of current and prospective demands, be cognizant of existing and developing inadequacies in distribution facilities, and will maintain a well-planned program of improvements to correct these inadequacies. Alert management also will keep its patrons fully informed as to the need for such improvements, the capital investment required, and the additional revenue which they must pay to support the additional investment. They make the decision as to whether the value of the more adequate service which the improved system will provide will justify the required investment and any proposed increase in rates.

Fire Flows Required for Towns of Various Sizes, by National Board of Underwriters

Population	Required Fire Flow, Gallons per Minute for Average City
1,000	1,000
2,000	1,500
4,000	2,000
6,000	2,500
10,000	3,000
13,000	3,500
17,000	4,000
22,000	4,500
28,000	5,000
40,000	6,000
60,000	7,000
80,000	8,000
100,000	9,000
125,000	10,000
150,000	11,000
200,000	12,000

Over 200,000 population, 12,000 gallons a minute, with 2,000 to 8,000 gallons additional for a second fire.

In residential districts the required fire flow depends upon the character and congestion of the buildings. Sections where buildings are small and of low height and with about one-third the lots in a block built upon, require not less than 500 gallons a minute; with larger or higher buildings up to 1,000 gallons is required, and where the district is closely built, or buildings approach the dimension of hotels or high value residences, 1,500 to 3,000 gallons is required, with up to 6,000 gallons in densely built sections of 3-story buildings.

Commercial Pipe Sizes for Fire Streams*

Number of 1 1/4-Inch Hose Nozzles	Ordinary Fire Streams											
	40 Pounds Pressure		50 Pounds Pressure		60 Pounds Pressure		70 Pounds Pressure		80 Pounds Pressure		90 Pounds Pressure	
	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.
1	4	20	6	23	6	25	6	27	6	29	6	30
2	6	40	8	45	8	50	8	53	8	57	8	61
3	8	61	8	68	10	74	10	80	10	86	10	91
4	10	81	10	90	10	99	10	107	12	114	12	121
5	10	101	12	113	12	124	12	136	12	143	12	152
6	12	121	12	135	12	149	14	160	14	172	14	182
7	12	141	14	158	14	174	14	187	14	200	16	212
8	12	162	14	181	14	199	16	214	16	229	16	242
9	14	182	14	203	16	223	16	241	16	257	18	273
10	14	202	16	226	16	248	16	267	18	286	18	303
11	16	222	16	248	18	273	18	294	18	314	18	333
12	16	243	18	271	18	298	18	321	20	343	20	364
13	16	263	18	293	18	323	20	348	20	372	20	394
14	18	283	18	316	20	348	20	374	20	400	20	424
15	18	303	20	339	20	372	20	401	20	429	24	455

	High-Pressure Fire Streams											
	100 Pounds Pressure		110 Pounds Pressure		120 Pounds Pressure		130 Pounds Pressure		140 Pounds Pressure		150 Pounds Pressure	
1	6	32	6	33	6	35	6	36	6	38	6	39
2	8	64	8	67	10	70	10	73	10	75	10	78
3	10	96	10	100	10	105	10	109	12	113	12	117
4	12	128	12	134	12	140	12	145	12	151	14	156
5	14	160	14	167	14	174	14	181	14	188	14	195
6	14	191	14	200	14	209	16	218	16	226	16	234
7	16	223	16	234	16	244	16	254	16	264	18	273
8	16	255	16	267	16	279	18	290	18	301	18	313
9	18	287	18	301	18	314	18	326	18	339	20	352
10	18	319	18	334	20	349	20	363	20	377	20	391
11	20	351	20	367	20	384	20	399	20	414	20	430
12	20	383	20	401	20	419	20	435	24	452	24	469
13	20	415	20	426	24	454	24	472	24	490	24	508
14	24	447	24	467	24	488	24	508	24	528	24	547
15	24	479	24	501	24	523	24	544	24	565	24	586

To convert cubic feet to gallons, multiply by 7.4805.
In calculating above table, the following assumptions were made: Nozzles, 1 1/4-inch smooth bore, playing simultaneously, and attached to 200 feet of best quality rubber-lined hose; pressures measured at hose connections; velocity of water in pipe approximately 5 feet per second.

Design Of Main Extensions Of Small Size

Where No Fire Service is Required

By D. R. TAYLOR

General Manager, Baton Rouge Water Works Co., Baton Rouge, Louisiana

ALL public water utilities are occasionally confronted with the necessity of making main extensions. Where fire protection is required, design techniques and methods have been more or less standardized and generally accepted. Frequently, however, for numerous reasons well known to the profession, only domestic service will be required for a long time or at least for several years and a small main extension is decided upon.

To design a main extension for domestic service only, the maximum domestic demand must be known. During the last decade much attention has been given this subject. With the use of the Meter Master, many tests have been and are still being made in many sections, to determine maximum domestic demand, and the results vary so greatly that it is difficult to form a conclusion. The difference of climatic conditions in various sections will of course affect the results, but, a considerable variance has been found also in the same section in several parts of the country.

Property Classification and Water Consumption

For several years tests have been conducted in Baton Rouge by metering the total consumption of various numbers of residences of various classifications of property in an effort to determine maximum domestic demand. The Meter Master has been used in each test to record the various rates of flow. It has been desired to determine the maximum demand during the longest, hottest, driest, period that might occur within ten years, when lawn sprinkling reached a maximum. The ten year period was considered to be reasonable and practical. While several droughts occurred during the period of the tests, none was considered to be the ten year maximum. Realizing that lawn sprinkling can increase the demand enormously, a substantial percentage was added to the results to simulate maximum drought conditions for such a period.

While the rates shown have proved sufficient for this locality, it is felt that subsequent tests may suggest some slight downward revision for the larger numbers of houses in Classes 3 and 4. Based on these rates, however, a review of the design of more than twenty miles of small main extensions ranging in length from 100 to 3000 ft., installed during the last five years, has proved that these rates are adequate.

In Table 1, Class 1 may be of little use to the average city, on the other hand the author has assisted several small towns with populations of less than 5000 that were more rural than urban, where prospective customers desired only a minimum of service and where either they could afford very little expense for the main extension or the town had practically nothing in its budget to defray the expense of the installation. In these instances, Class 1 rates were satisfactory to all concerned. This class is included for those who are forced to resort to its use.

Table I

Maximum Domestic Demand in G.P.M.

For various types of houses with tank-type toilets.

Number of Houses	CLASS OF PROPERTY			
	1	2	3	4
1	10	12	14	19
2	12	15	18	24
3	14	17	20	27
4	16	19	22	30
6	18	21	25	34
8	20	23	28	37
10	21	25	30	40
15	25	30	37	50
20	28	35	43	58
25	30	39	48	66
30	31	42	53	73
40	36	48	62	85
50	40	54	70	96
60	43	59	76	105
70	45	62	82	115
80	48	68	88	125
90	50	71	94	132
100	52	75	100	140
125	57	83	110	157
150	61	90	120	175
175	64	97	132	190
200	68	105	140	205
300	80	125	175	250
400	90	145	200	295
500	100	160	225	335

DESCRIPTION

CLASS 1 Sub-Standard houses with barest minimum of plumbing where little or no lawn sprinkling is expected.

CLASS 2 Small houses with one bath, on small lot. Small rental houses and small rental duplex houses. Very little lawn sprinkling. Either side of a duplex is considered as one house.

CLASS 3 Average good sub-division with 80% two to three bedroom houses with one bath and 20% two to three bedroom houses with two baths. Houses owned by occupant, with average amount of lawn and shrubbery requiring average amount of lawn sprinkling.

CLASS 4 Houses with three to four bedrooms and two to three baths on large lots requiring considerable lawn sprinkling. Does not include estates with or without swimming pools.

Loss of Head in Pipe

In Baton Rouge, raw water from deep wells has a total hardness of zero, a total alkalinity of 170, of which 150 ppm. is due to bicarbonates, a pH of 8.7 and requires no treatment. Mains 20 years old have a C of 120 or more.

The losses of head in Fig. 1 are based on actual inside diameter instead of nominal diameter. The sizes marked G. S. represent galvanized standard weight steel pipe. While all sizes of steel pipe are designated by nominal diameter, the various sizes of cast iron pipe are designated by actual diameter. This has been done for the following reason: All standard weight steel pipe is made to the same specifications by the various manufacturers, but the inside diameter of some small sizes of cast iron pipe varies with different manufacturers. Therefore, it seems appropriate to indicate the nominal diameter of galvanized steel pipe and actual diameter of cast iron pipe. In any event the actual diameter of the pipe being considered should be known. If it is desired to design with a C other than 120, the values in Fig. 1 should be multiplied by the proper multiplier shown in the following table:

Value of C	140	130	120	110	100
Multiplier	.75	.86	1.0	1.17	1.4

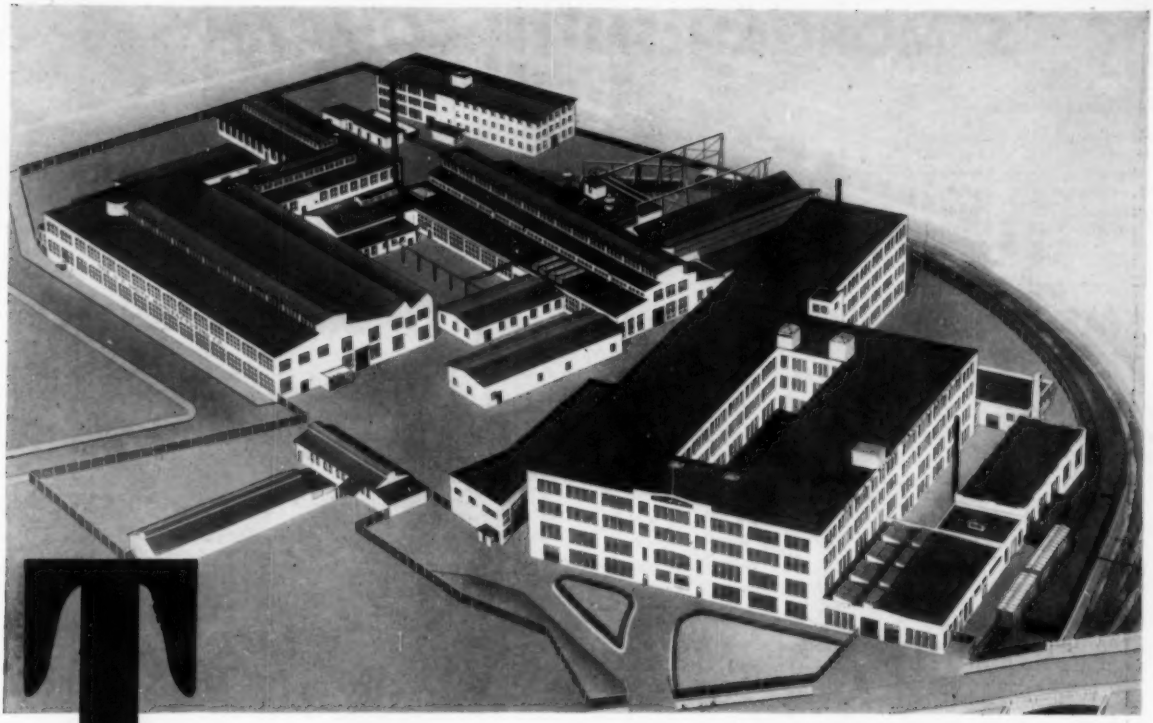
The small sizes of cast iron pipe are very popular for small main extensions because of the cast iron permanence and because of this small cast iron pipe can be salvaged, when replaced with larger mains to provide fire protection, and reused as often or as long as desired.

The curve in Fig. 2 was derived from the formula,

$$F = \frac{\Sigma N^m}{N^{m+1}}$$

Where N = Number of houses
m = 1.85

This formula was designed to determine the total friction loss in a pipe line with any number of outlets, an equal distance apart and all discharging at the same rate. (When $N=1$, $F=1$) It may be considered that these two conditions are satisfied when all of the lots are of the same width and all of the houses are of the same class. A slight variation in these conditions on a relatively



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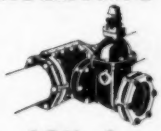
produces, **FIRE HYDRANTS A. W. W. A. Specification and High Pressure — Compression Type — Dry and Wet Barrel Types.** **GATE VALVES sizes 2" thru 66", Manual, Hydraulic Cylinder, Electric Motor Operated for Low, Medium and High Pressure Service.** **INSERTING VALVES sizes 4" thru 48" for inserting under pressure.**  **TAPPING SLEEVE AND VALVES sizes 4" x 2" thru 60" x 48" for branch connections under pressure.**

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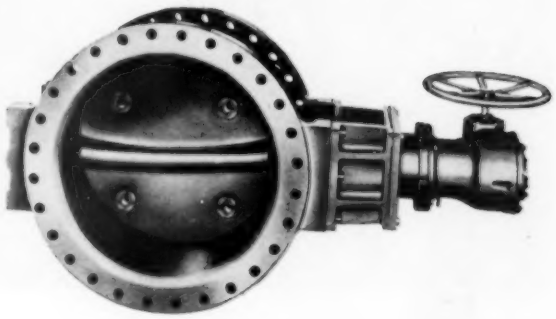
MORE COMPACT and lighter in weight than most types. They permit concise layouts with direct savings in construction and in-place costs. Valves are made in all materials that can be cast or welded. Metal-seated valves can be built to operate over any range of temperature, either sub-zero or elevated. Babbitt or rubber seats meet a wide range of pressure and closure conditions. Rubber-seated butterfly valves are drop tight at 125 psig through a temperature range from plus 200°F to minus 20°F.

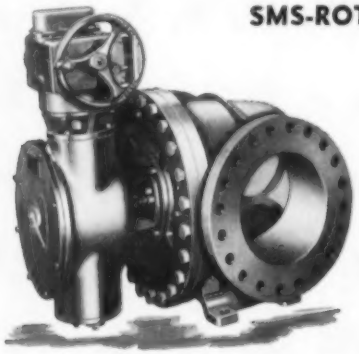
COMPLETE CONTROL in all positions of normal regulating range. The valve can be equipped with positioner to simulate a straight linear or semi-log characteristic.

ALL TYPES of operators are available. Closure time can be furnished from 1 second to 10 minutes or more to meet operation needs.

MINIMUM PRESSURE DROP SAVES POWER. In open position the streamlined valve disc simulates a Venturi action. Pressure drop is less than in many other valve types resulting in substantial savings in pumping power.



A 50# rubber-seated valve with totally-enclosed manual operator. R-S rubber-seated valves have a tough, resilient rubber seat which positively seals the disk periphery and shaft bosses.



SMS-ROTOVALVES FOR RUGGED SERVICE . . .

THE ROTOVALVES' full line opening offers no more resistance than a straight piece of pipe of the same diameter. Less resistance means less head loss for the lowest pumping costs obtainable. SMS-Rotovalves are the proven answer to many control problems. The principle of hydraulic imbalance assists closing for faster, easier operation. One Rotovalve can often replace two or more conventional valves for faster, more positive closure and control of water hammer.

WEAR FACTOR is negligible with Rotovalves. In operation the conical plug first lifts, then rotates, finally reseats in either open or closed position. This action ensures *tight, positive seating* throughout valve life by avoiding wear and abrasion at the valve seats.

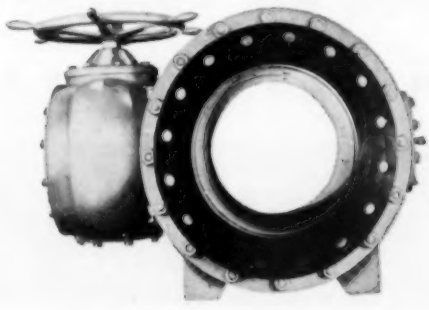
SMS BALL VALVES GIVE STRAIGHT-THROUGH FLOW

BALL VALVES are similar in flow characteristics to SMS-Rotovalves. They do not seat in the open position, and have slightly greater head loss than Rotovalves.

TIGHT CLOSURE is assured by the wedging action of the metal-to-metal seats.

EASE OF OPERATION results from tremendous leverage and the fact that flow velocity tends to ease closure.

SMS BALL VALVES provide across the board economy—lower first-cost, lower pumping costs and extended line and valve life.



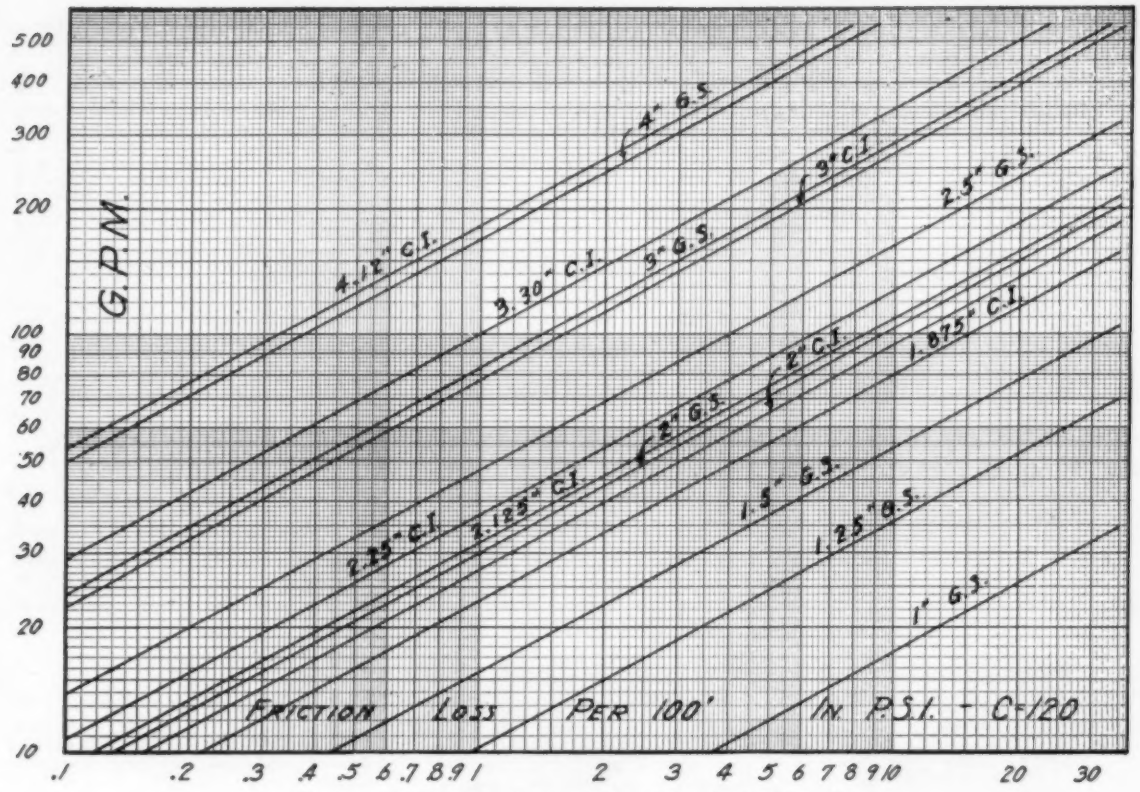


Fig. 1—Loss-of-Head in PSI per 100 ft. of Pipe With "C"= 120

short extension of one size will make little difference.

There may be rare instances, especially on a long extension, consisting of two sizes of pipe, when there may be some considerable variance in these two conditions along the extension or the width of the lots and/or class of houses may be different at either end of the extension. In such instances the use of a little practical judgment in making reasonable prorations to fit the conditions, will provide satisfactory results. In this case "N" is designated as the "number of houses," assuming that there is a separated outlet (tap) for each house.

When taps for two houses on opposite sides of the street are very close together on the main they should be considered as one "outlet" or "house" and the rate per house multiplied by two. For instance, if this condition existed for 40 houses (20 on either side of the street) on fifty foot lots along an extension 1000 ft. long, it should be considered that N=40÷2=20. If these were Class 3 houses the rate per house (from Table 1) would equal 62÷20=3.1 gpm.

The amount of residual pressure to be provided at the tap is a matter of opinion or policy. It may vary from 25 psi. for single story Class 2 houses to 40 psi. for two story Class 4 houses.

Total friction loss in a main extension for domestic service, expressed in pounds per square inch, equals length of the extension in hundreds of feet, times friction loss per 100 ft. in pounds per square inch, times factor (F). For example, assume that a 2-in. G.S. main with a C of 120, 500 ft. long, fed from only one end, serving 10 houses, has a maximum demand of 40 gallons per minute. What is the total friction loss in this main?

From Fig. 1, friction loss for 2-in. G.S. pipe at 40 gpm. is 1.7 pounds per square inch per 100 ft. and from Fig. 2, for 10 houses F is .404. Therefore, total friction loss=5×1.7×.404=3.43 psi.

The Design Process

PROBLEM 1: A 1500 ft. main extension is required to serve 60 Class 2 houses on 50 ft. lots (30 on either side of the street) and the main will be fed from both ends. The daily minimum distribution system pressure is 50 psi. and a residual pressure of 30 psi. is desired at each tap. Therefore, only 20 psi. can be allowed for friction loss, 50—30=20. Assume that 1½ in. galvanized steel pipe with a C of 100 will be required.

1st Trial Calculation

From Table 1, maximum demand for 60 Class 2 houses = 59 gpm.
From Fig. 1, friction loss through 1½ in. G.S. pipe for 59 gpm. = 11.8 psi per 100 ft.
From Fig. 2, for 60 houses, F = 0.358.

Values in Fig. 1 are for a C of 120 and must be multiplied by 1.4 for a C of 100. This extension will be fed from both ends, therefore the total friction loss calculated as if it were fed only from one end must be divided by $2^{1.85}$ i.e., (3.6) or multiplied by the reciprocal of $2^{1.85}$ i.e., (.278).

Total friction loss
15 × 11.8 × 1.4 × .358 × .278 = 24.66 psi.

This exceeds the friction loss of 20 psi. that can be allowed, so the calculation should be repeated for pipe a size larger, as for instance 2 in. cast iron pipe.

2nd Trial Calculation

From Fig. 1, friction loss through 2 in. C.I. pipe for 59 gpm.
= 4.2 psi. per 100 ft.

Total friction loss
= 15 × 4.2 × 1.4 × .358 × .278 = 8.75 psi.

A 2 in. cast iron main will satisfy the maximum demand with a residual pressure of approximately 41.25 psi. at the taps.

PROBLEM 2: A 3000 ft. extension is required to serve 120 Class 3 residences on 50 ft. lots. The daily minimum distribution system pressure is 60 psi. and a residual pressure of 35 psi. is desired at each tap. Therefore, only 25 psi. can be allowed for friction loss, 60—35=25.

From Table 1, maximum demand for 120 Class 3 houses=108 gpm.* Assume that 1500 ft. of 3.30 in. cast iron and 1500 ft. of 2½ in. cast iron pipe with a C of 120 will be required.

1st Trial Calculation

1500 ÷ 50 × 2 = 60 houses on 3.30 in. main
1500 ÷ 50 × 2 = 60 houses on 2½ in. main
108 ÷ 120 = 0.9 gpm. per house
60 × 0.9 = 54 gpm. = maximum demand for 3.30 in. pipe
60 × 0.9 = 54 gpm. = maximum demand for 2½ in. pipe

Average rate of flow through the 3.30 in. pipe equals influent rate, plus effluent rate, plus rate per house, divided by 2.

Influent rate of 3.30 in. pipe =	108.0 gpm.
Effluent rate of 3.30 in. pipe =	54.0 gpm.
Rate per house	.9 gpm.
Total	162.9 gpm.

Average rate through 3.30 in. pipe
= 162.9 ÷ 2 = 81.45 gpm.
From Fig. 1, loss through 3.30 in. pipe for 81.45 gpm.
= .67 psi. per 100 ft.

*By interpolation

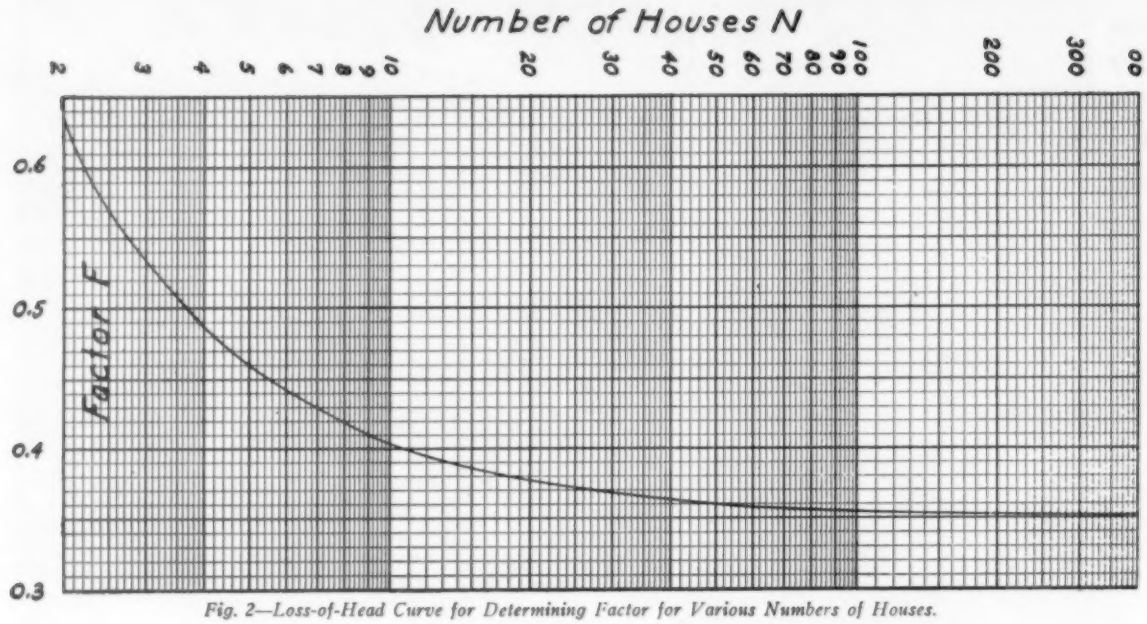


Fig. 2—Loss-of-Head Curve for Determining Factor for Various Numbers of Houses.

Therefore, total loss through the 3.30 in. pipe
= 15 × .67 = 10.05 psi.
From Fig. 1, loss through 2½ in. pipe for 54 gpm.
= 2.7 psi.
From Fig. 2, for 120 houses
F = .355
Therefore, total loss through 2½ in. pipe
= 15 × 2.7 × .355 = 14.35 psi.
Total loss through 3.30 in. and 2½ in. pipe
= 10.05 + 14.35 = 24.40 psi.

An extension consisting of 1500 ft. of 3.30 in. pipe and 1500 ft. of 2½ in. pipe will satisfy the maximum demand with a residual pressure of approximately 35.60 psi. at the taps.

PROBLEM 3: A 3000 ft. extension is required to serve 120 Class 3 houses on 50 ft. lots. The daily minimum distribution system pressure is 50 psi. and a residual pressure of 25 psi. is desired at each tap. Therefore, only 25 psi. can be allowed for friction loss, 50—25=25. The taps for each pair of houses on opposite sides of the street will be made within one foot of each other, along the main. In this case the extension will be fed from *both* ends and it is desired to use as much 2 in. galvanized steel pipe as possible and as little of the next larger size as will be required.

From Table 1, maximum demand for 120 Class 3 houses=108 gpm. Assume that 500 ft. of 2½ in. and 2500 ft. of 2 in. galvanized steel pipe with a C of 120 will be required.

1st Trial Calculation

500 ÷ 50 = 10 houses on 2½ in. main
(Each pair of taps made close together)
2500 ÷ 50 = 50 houses on 2 in. main
10 + 50 = 60
108 ÷ 60 = 1.8 gpm. per house
10 × 1.8 = 18 gpm. = maximum demand for 2½ in. pipe
50 × 1.8 = 90 gpm. = maximum demand for 2 in. pipe
Influent rate of 2½ in. pipe = 108.0 gpm.
Effluent rate of 2½ in. pipe = 90.0 gpm.
Rate per house = 1.8 gpm.
Total = 199.8 gpm.
Average rate thru 2½ in. pipe
= 198.8 ÷ 2 = 99.9 gpm.
From Fig. 1, loss thru 2½ in. pipe for 99.98 gpm.
= 4 psi.
Therefore, total loss thru the 2½ in. pipe
= 5 × 4 = 20.0 psi.
From Fig. 1, loss thru 2 in. pipe for 90 gpm.
= 7.7 psi.
From Fig. 2, for 60 houses
F = .358
Therefore, total loss thru the 2 in. pipe
= 25 × 7.7 × .358 = 68.9 psi.
Total loss thru 2½ and 2 in. if fed from one end
= 20.0 + 68.9 = 88.9 psi.
Total loss if fed from both ends
= 88.9 × .278 = 24.7 psi.

This extension will satisfy the maximum demand with a residual pressure of approximately 25.3 psi.

The values shown in Table 1 are not considered to be the perfect answer. The matter of maximum domestic demand may never be reduced to an "exact science." Considerable research, however is being conducted in various sections of the country and results are looked forward to by the profession with much interest. The values used herein have been obtained in a southern state where the growing season is long and the summer temperature is high. There are many garden clubs and an amazing interest is shown in growing semi-tropical plants, including camellias which may cost as much as $50.00 each, for a rare variety, several years old. For obvious reasons there is considerable sprinkling. Therefore, these maximum domestic demand values may be slightly high for other sections of the country.

These values are offered as a basis for further study and for use in design, until such values are determined for the particular section in which they may be used, if conditions in that section require that other values be used.

Useful Information

1 cubic foot of water @ 62° F.	=	Weighs 62.36 pounds
1 U. S. gallon of water @ 62° F.	=	Weighs 8.33 pounds
1 U. S. Gallon	=	.231 cubic inches
1 U. S. gallon	=	.0.13367 cubic feet
1 cubic foot	=	.7.48 U. S. gallons
1 Imperial gallon	=	1.2003 U. S. gallons
1 litre	=	0.26417 U. S. gallons
1 cubic meter	=	264.2 U. S. gallons
1 foot depth of water @ 62° F.	=	0.433 lbs. (per sq. in.) pres.
1 pound (per square inch) pressure.	=	2.309 feet depth of water
1 horsepower	=	550 foot pounds per second
1 horsepower	=	33,000 foot pounds per min.

1 kilowatt	=	1000 watts
1 kilowatt	=	1.341 horsepower
1 horsepower	=	0.7457 kilowatts
1 cubic inch cast iron		Weighs 0.260 pounds
1 cubic foot cast iron		Weighs 450 pounds
1 cubic inch steel		Weighs 0.2835 pounds
1 cubic foot steel		Weighs 490 pounds
1 cubic foot cement (1 bag)		Weighs 90 pounds
1 cubic yard sand		Weighs 2700 pounds approx.
1 cubic yard gravel		Weighs 2700 pounds approx.
1 cubic foot common brick		Weighs 120 pounds approx.
1000 brick		Weigh 5300 pounds approx.

Formulas for Calculating Areas and Volumes

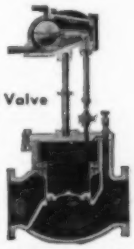
π	=	3.1416
Circumference of circle	=	Diameter × π
Area of circle	=	Radius² × π
Area of sphere	=	4 × radius² × π
Volume of sphere	=	⅔ × diameter³ × π
Area of PDM semi-ellipse	=	1.237 × (diameter of tank)²
Volume of PDM semi-ellipse	=	.0.17431 × (diameter of tank)³
Area of cone or pyramid	=	Perimeter of base × ½ slant ht.
Volume of cone or pyramid	=	Area of base × ⅓ of height perpendicular to base
Area of frustrum of cone or pyramid	=	(Perimeter of base + perimeter of of top) × ½ slant height.

GOLDEN-ANDERSON VALVE SPECIALTY COMPANY

1246 Ridge Avenue, Pittsburgh 33, Pa.

Cushioned Water and Steam Control Valves

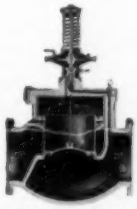
Specifically designed for municipal water works systems



Cold Water Float Valve

Self-contained, accurate water level control—for high pressure.

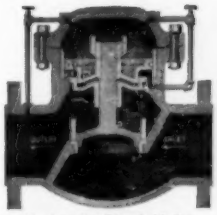
BULLETIN W-5



Altitude Control Valve

For accurate water level control in tanks, reservoirs, etc.

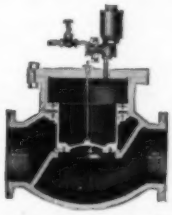
BULLETIN W-4



Hydraulic Check Valve

Cushioned check valve for use with reciprocating pump.

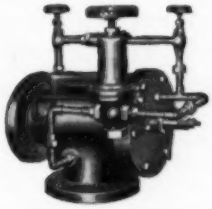
BULLETIN WS-1



Solenoid Operated Electric Water Service Valve

Full-ported-cushioned-sizes to 36". Adjustable operating speeds.

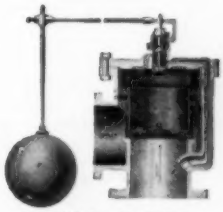
BULLETIN W-7



Surge Relief Valve

Prevent hammer and shock—fast opening—slow closing cushioned valve—sizes to 36".

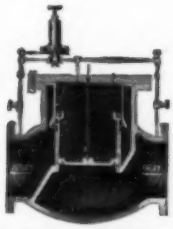
BULLETIN W-2



Cold Water Float Valve

Water level control—open tanks cushioned to high pressure service.

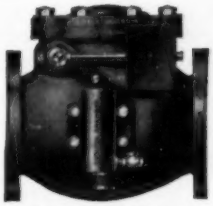
BULLETIN W-5



Water Pressure Reducing Valve

Cushioned reducing valve—wide range adjustment—tight closing.

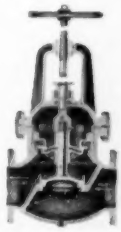
BULLETIN W-3



Swing Check Valve

Cushioned only on last 5% of stroke—fast closing.

BULLETIN W-1



Automatic Turbine Stop Valve

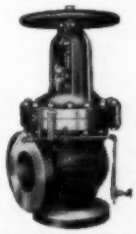
Prevent fly-wheel explosions and overspeed on turbines.

BULLETIN S-3

Single-Acting Non-Return Valve

Cushioned check valve to prevent return flow of steam.

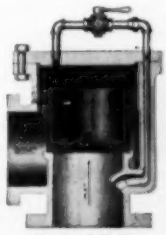
BULLETIN S-2



Triple-Acting Non-Return Valve

Closes on ruptured boiler tube or on ruptured header-protection both ways.

BULLETIN S-1A



Flowtrol Valve

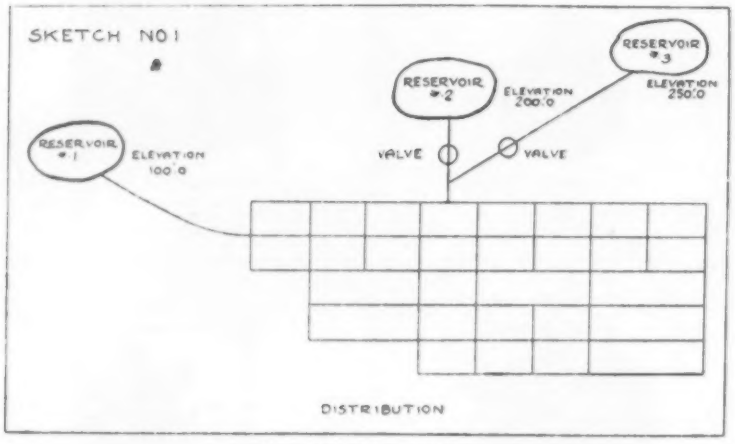
Used instead of hard-to-open gate or plug valves—simple and positive.

BULLETIN W-8A

Write for our detailed Technical Bulletins

Application of Altitude Valves and Pressure Regulators

By WILLIAM F. END
Engineer and Treasurer, Ross Valve Mfg. Co.
Troy, N. Y.



Valves to Balance Head

THE SUBJECT matter of this paper is a review of the practical and successful installation and operation of automatic valves — some having been in service (and on 24-hour duty) for a half century.

Along with the development of the science of supplying pure water, has grown the closely allied work of distributing this water to the population being served. As the areas of population have expanded with the evolution of running water at the tap in the household, and the extinction of the public well, so likewise have the problems of pressures and pressure control expanded.

The old adage, "You never miss the water till the well runs dry" was never more true when applied to the present-day water supply. From the standpoint of health, and the danger of fire hazard to a community, even a temporary shut-down of service or pressures in a public water supply is of serious consequence.

The magnitude and responsibilities of the present-day water supply system have necessarily caused water works engineers and operators to turn to the use of automatic devices for increasing the efficiency and reliability of the service. Let there be no mistake about the responsibility of these individuals; theirs is a 24-hour job subject to the mandates of the commission, politicians, and individual consumer. To provide anything but a miserable existence for the operator, it becomes a "must" to have in the system devices such as automatic valves and automatic equipment.

The advantages of an automatic pressure control valve, properly designed, installed and maintained, permit flexibility within the system because of the ability of this device to adjust itself for the normal and abnormal conditions over the 24-hour day; and without undue attention by the operator.

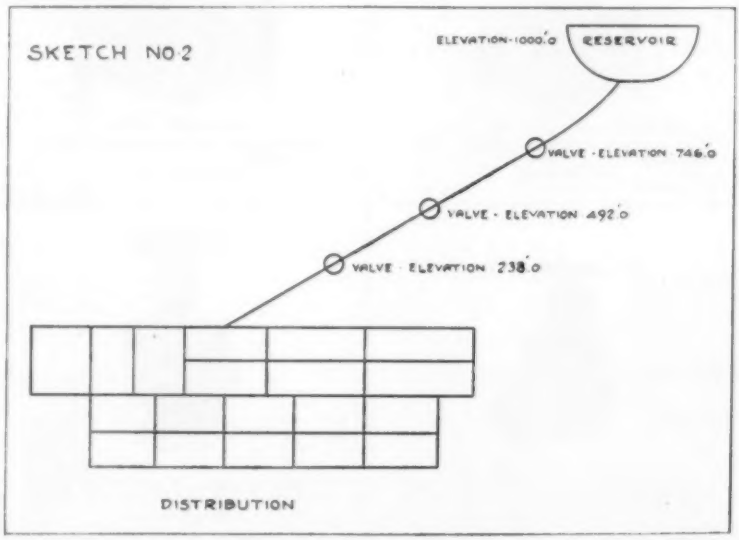
Types of Automatic Valves

There are four standard types of automatic valves, any one or combination (a single unit having two or more controls) of which may serve in the control of flow or pressures—thereby increasing the efficiency of the complete water supply system. A gravity or pump supply with or without tanks floating on the system undoubtedly will have need for some type of automatic valve which will correct unbalanced or excessively high pressures.

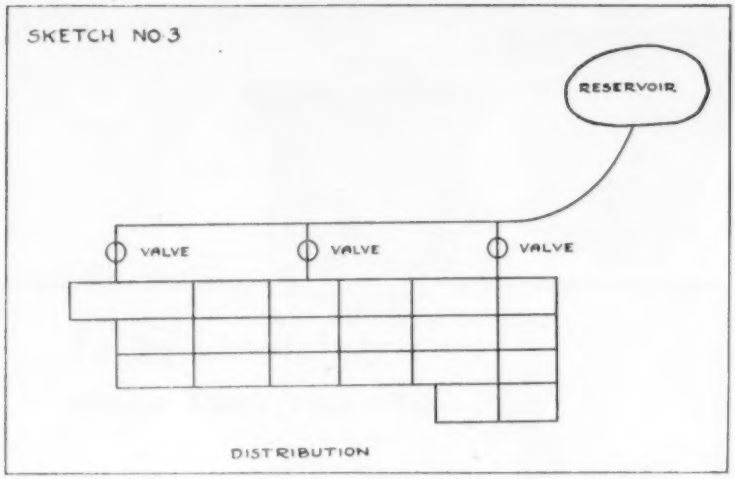
The four basic or standard types of automatic valves may be identified as: 1. Pressure Reducing, 2. Altitude, 3. Relief-Surge-Back Pressure, and 4. Float.

Pressure Reducing Valves

The first of these valves made its appearance in the waterworks field as a throttling orifice in London about 1700. Constant pressure reduction was, of course, possible only with a uniform rate of flow. The engineer



Valves to Reduce Static Pressure



Valves to Balance Unequal Pressure

soon devised a means of changing automatically the size of orifice (in smaller valves only). This device was in the form of stem movement into and out of the valve seat. While the change was an improvement, the design made use of an unbalanced stem and was considered by qualified students to be bad practice.

As late as the 1870's, presure reduction in water supply for pipe lines larger than 3" was accomplished by what was known as *break-point basins*. Water discharging from a pipe into these small basins would reenter the pipe at about zero pressure; and, depending on the head or pressure to be dissipated, one or more break-points were a part of the gravity pipe line from reservoir to distribution. By this method of pressure reduction, control for the varying rates of flow was difficult and resulted on the one hand in overflow of the basin with consequent waste of water; and, on the other hand, drainage of the basis and entrained air in the pipe line. The engineer's problem of maintaining adequate flow, pressure reduction and elimination of air and waste was ultimately solved by replacement of break-point basins with the pressure reducing valve.

A valve which will maintain constant pressure at its discharge side is considered a *pressure reducing valve*. In the sketches immediately following are illustrations of the use of this valve adapted for the particular need in conduit from reservoir to distribution.

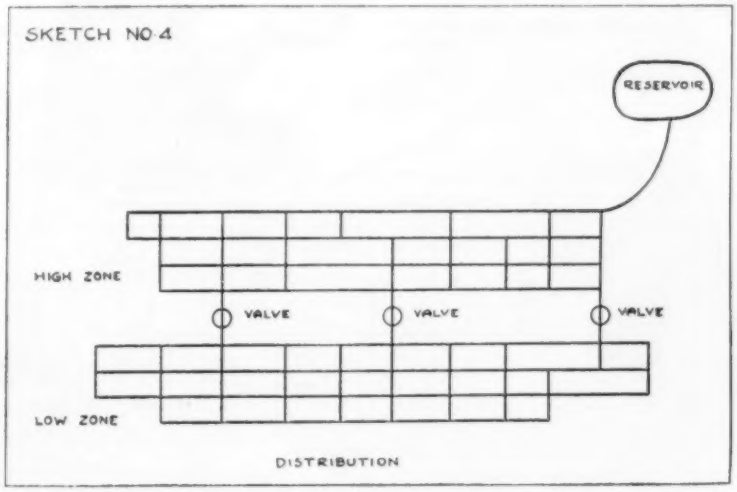
Sketch No. 1 shows reservoirs and a distribution system in which, as the extensions enlarged the system, additional reservoir or storage is required. Since reservoirs normally cannot be located at one elevation, the problem of heads becomes one of the balancing of pressures; and the need, therefore, of automatic devices. Pressure reducing valves in the pipe lines from the reservoirs of higher elevation may be adjusted to discharge into the system at the same head as that available from the low reservoir.

Sketch No. 2 is another illustration showing the need of pressure reduction in a pipe from a reservoir having an elevation (let us assume) 1000 ft above the distribution system. If the satic pressure of 1000 ft (or approximately 435 lbs) were to enter distribution, with no stretch of imagination one may visualize the problems with which the operator would be confronted. Three stations of pressure reduction from 110 lbs to 10 lbs each would dissipate approximately 700 ft or 300 lbs of static head; and allow approximately 100 lbs pressure to safely enter the distribution.

Sketch No. 3. Where, because of the contour of the terrain, a community is inflicted with a distribution which has much greater length than breadth, and a supply entering at one end, the problem of unequal pressures because of head loss is a major one. Assuming the trunk main runs the length of the distribution system, uniform pressure may be had throughout the entire length of the system by supplying water through pressure reduction chambers located at strategic points along the feeder main.

Sketch No. 4. A community located on a side hill, with little or no flat land, presents a problem of pressure zoning; and suggests inter-connection of these zones by pressure reducing valves. When our forefathers chose to settle on the banks of a river in mountainous and semi-mountainous country, they had in mind water transportation and water supply in the form of the hand pump and bucket. Expansion and development was adjacent to the river; however, when expansion (prompted by the river flooding low lands or for other reasons) started movement up hill to higher ground, the settlers promptly engineered the first of our gravity supplies. As the community or city grew upon a side hill, so also grew the problem of constant and uniform pressures, resulting in the development of pressure zoning and the further need of the pressure reducing valve.

Sketch No. 5. In passing, comment should be made on the so-called "sleeping valve." This valve (pressure reducing) located between two systems, zones or districts, opens occasionally only for a pre-adjusted pres-



Valves to Zone Pressure

sure to supply makeup water for the zone on the discharge side of the valve. The valve also may be made to allow a reverse flow if there is need for such provision.

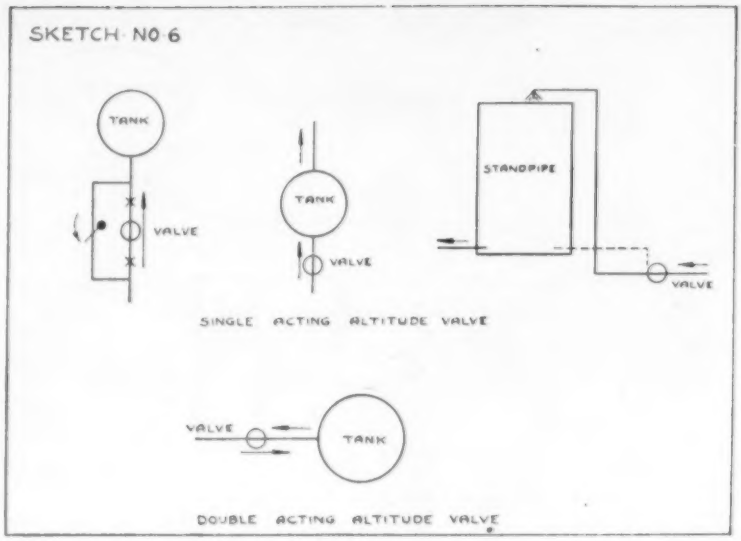
Altitude Valves

The altitude valve, another of the four standard automatic valves, attracted attention and interest when standpipes and elevated tanks were accepted by the waterworks profession as efficient instruments in the operation of the distribution system. The valve increased the value of the tank by effectively controlling the water storage.

Filling a tank on the off-peak load and automatically isolating the tank for use during peak loads is the service which altitude valves contribute to the efficient performance of the tank and, consequently, to the overall efficiency of the system. The use of this valve is not confined to tanks alone, for they are used on open and closed reservoirs in filtration plants, and in aerator basins.

In specifying an altitude valve, one usually calls for a single or double acting valve, amplifying in the specifications a particular feature — depending on the service requirements. If an assembly so specified does not make of the valve a combination valve (an assembly to be treated in subsequent remarks) the valve is classified as a single or double acting altitude valve.

Sketch No. 6. A single acting altitude valve is one which permits flow into the tank or reservoir and closes to prevent overflow. Discharge from tank or reservoir is taken through a separate pipe or a bypass and swing check around the altitude valve.



Single and Double Altitude Valves

A single acting valve may have an external control which will allow the stem in the main valve to operate in two positions—wide open and closed —or as a throttling valve where the main stem floats on the column of water, gradually closing as the water rises in the tank or reservoir.

The double acting valve opens wide to pass water into the tank, closes to prevent overflow, and opens wide for reverse flow from tank to distribution. The installation of this valve would therefore require but a single pipe for supply to and discharge from the tank.

The location of an altitude valve should be adjacent to the tank or reservoir, or as near as construction obstacles will allow. Such location will permit communication to the pilot of the true static head of water in the tank, which otherwise is not possible because of friction loss between valve and tank. A true static pressure communication to pilot will guarantee sensitive and accurate control of the tank.

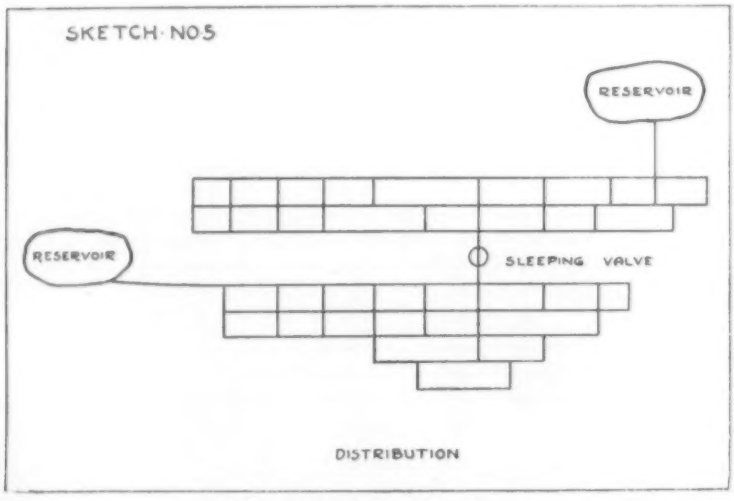
Altitude valves are normally controlled by hydraulic pilots; however, both the single acting and double acting altitude valves may be controlled by a three-port solenoid which is actuated (energized or de-energized) by a float or pressure switch.

Relief or Surge Valves

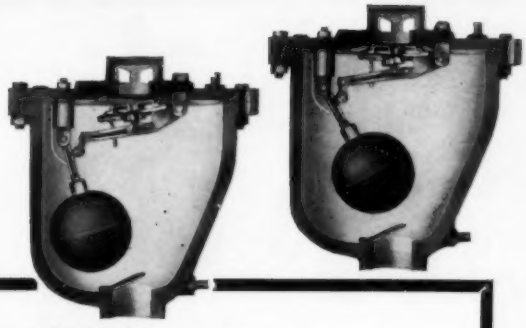
The relief or surge valve, sometimes called back pressure valve, is another of the four standard types of automatic valves in use in the waterworks field. This valve responds to pressures at its inlet side rather than to pressures at the discharge side, as is the case of the pressure reduction valve or the single acting altitude valve.

When referred to as a relief valve, it is considered an automatic device for releasing a gradual pressure rise which may, without correction, subject a pipeline to a rupturing pressure. The installation is made where there is easy disposal of the wasted water necessary to dissipate the pressure wave or back-flow surge within the line. The location of the valve may be in a side outlet discharging to a stream, well, or zone of lower pressures.

In terms of a surge valve, we think of the valve as an automatic device which will arrest sudden pressure rise —the intensity of which may produce hammer in the pipeline. Installation



Valves to Supply Make-Up Water



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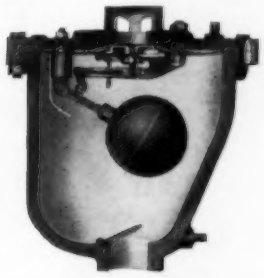

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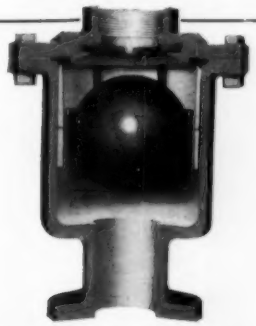

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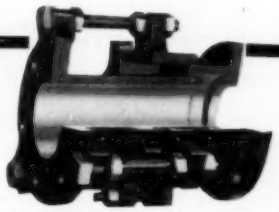
Permit air to escape as line fills, allows air to enter as line empties—*no danger of collapsed pipes.*



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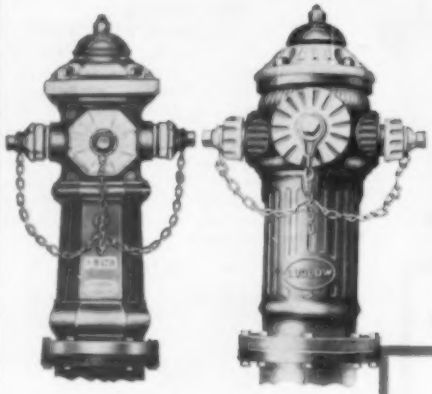
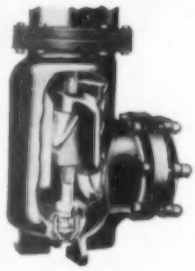


LIST 90-0 LIST 75-0



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13

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CHECK VALVES • TAPPING SLEEVES • AIR RELEASE VALVES

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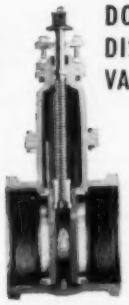
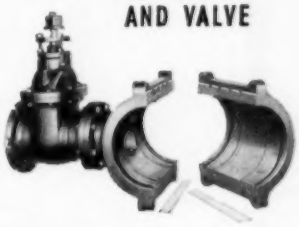


DOUBLE DISC VALVE



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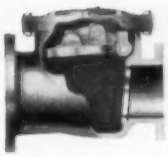
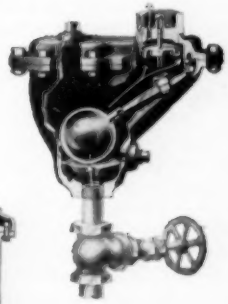
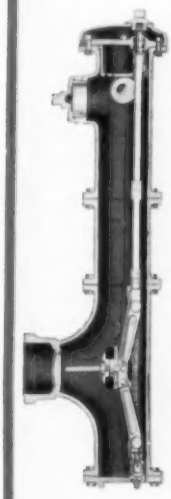
14



CHECK VALVE



AIR VALVE



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may be as mentioned above or, where used in conjunction with pumps, in a bypass around swing check and pump to the suction.

As a back pressure valve, we think of an installation where the upstream pressure (not to exceed a predetermined amount) is to be maintained. When performing as a back pressure valve, the valve passes or discharges only that volume of water which will hold the upstream pressure of that desired. This type of service is advantageous in a system of two zones where one (during certain periods of the day) may waste a volume above its requirements to another. The valve will pass only the amount of water limited by the adjustment of the pilot so that the zone receiving this water cannot receive an overdraft through the valve.

A valve of this description (in addition to the use just described) may serve as a protective measure against over-drafting by deep well pump. Also, installed in a service reservoir receiving water from a storage reservoir, the valve may be adjusted to throttle flow; and, at the same time, maintain pressure on aerator nozzles for aeration.

Float Valves

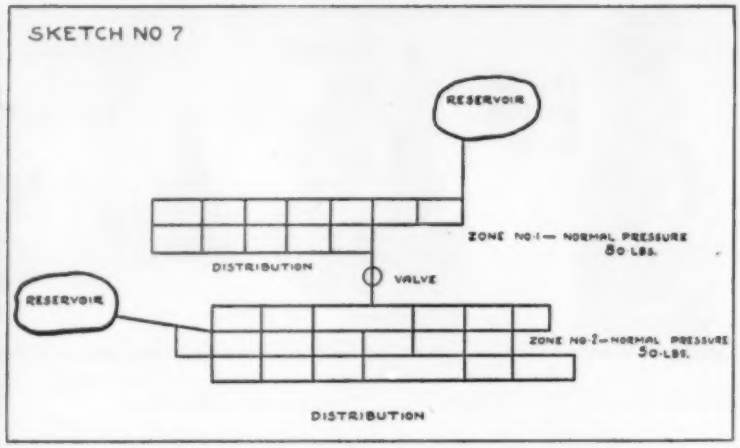
Another of the standard automatic valves is the float valve. This assembly may be specified as direct acting (with float and lever arrangement) or with main valve stem supported by large float (hydraulic pilot operated or solenoid pilot operated). In any case, a float is the prime mover and is directly or indirectly responsible for movement of the stem in main valve.

As a direct acting valve, the operation is throttling; however, as hydraulic pilot controlled valve, its operation may be throttling or the stem may be made to assume a wide open or closed position. When a solenoid pilot is used in conjunction with a float switch to actuate in the main valve, the stem operates in either a wide open or closed position.

In the waterworks field, the float valve is used extensively in warm climates where freezing will not interfere with the movement of the float; however, in colder climates where the use of the valve is a problem (due to its exposed mechanism) the operator may substitute some form of altitude valve.

Combination Valves

At this point, having covered the four standard assemblies of automatic valves, it would be an oversight if we failed to comment on the combination valve. These have only in recent years been recognized as a further step toward more efficient control of the water supply system—not alone in the light of economy as labor saving devices, but a means of obtaining 24-hour regulation and uninterrupted service.



Combined Pressure Reducing and Back Pressure Valve

These valves, a combination of two or more of our four standard automatic valves, may be arranged to control flows or pressure in one or both directions through the valve. Two or more hydraulic pilots or solenoid pilots, or combination of both, may (as conditions require) be a part of the external control. To those of us who have not had experience with a combination valve, it may be advisable to refer to one or two of these valves.

Sketch No. 7. In this sketch, two separate systems are illustrated:

Zone No. 1 with a normal pressure of 80 lbs and Zone No. 2 with a normal pressure of 50 lbs. The problem assumed is one in which Zone 1 can assist Zone 2 which (during periods of high draft) experiences a lowering of pressures. Other conditions involved are the excessive pressures which Zone 1 may place on Zone 2; and the possible overdrafting of Zone 1, particularly in the event of fire in Zone 2. Also, in the event of fire in Zone 1, priority must be given to Zone 1 for fire flows.

The valve which will meet these requirements is a combination valve having two hydraulic pilots in series—one to control the valve as a pressure reducing valve so that discharge into Zone 2 is held to a predetermined pressure; the other pilot to control as a back pressure valve and insure against overdrafting Zone 1. The valve, therefore, is a combination pressure reducing and back pressure valve.

The predetermined safe pressure for Zone 2 is 60 lbs—therefore, the pressure reducing pilot has the responsibility of delivering the safe pressure. Obviously, Zone 1 is to have priority; therefore, to avoid overdraft by Zone 2 in event of fire or break in this Zone 2, a predetermined pressure adjustment on the back pressure pilot is to provide the necessary protection. If this adjustment is 45 lbs, and for any reason consumption in Zone 2 is excessive (and the pressure in Zone 1 becomes less than 45 lbs) the valve closes or throttles.

The following will identify a combination altitude and back pressure valve controlling a tank—operating in conjunction with pumps taking suction from the tank. This valve is to pass water into the tank (however for two predetermined back pressures on the distribution), close to prevent overflow; and, when pumps are taking suction, the valve remains closed to prevent circulation thru the valve to tank.

The conditions of operation as planned are such as to require three hydraulic pilots and two solenoid pilots. In performing automatic operations as above, two hydraulic back pressure pilots are in parallel (one in series with electrical solenoid and pumps—the other hydraulic pilot in series with solenoid to be manually operated by a switch located at a remote point.) The third hydraulic pilot, for closing to prevent overflow of the tank, is in series with the two parallel hydraulic pilots and their respective solenoids.

In conclusion, it can be said that the use of automatic valves has been, is, and will always be essential to the efficient operation of water works system.

Lubricated Plug Valves for Water Works

by T. H. M. TAYLOR

Chief Engineer, Nordstrom Valve Div., Rockwell Manufacturing Co., Pittsburgh, Pa.

BECAUSE of its quarter-turn opening and closure, its tight positive shut-off, and its relative ease of operation, the lubricated plug valve is finding wider application in the water works field, both in the distribution system and the treatment plant.

Water works engineers are already familiar with the simple plug-type valve in the form of plug cocks or gauge cocks. The latter are used for isolating gauges and other instrumentation. Every distribution system has a service cock on the main. Multiport plug cocks are used as pressure controls on hydraulic cylinders which operate large valves.

But compared with the lubricated plug valve, the common plug cock is a relatively crude piece of equipment with limited application. The lubricated plug valve is engineered and precision built so that it has a long service life in a wide variety of applications and fields. It is available in sizes, pressure ratings and port openings comparable to standard gate and globe valves. It can be hand-operated by wrench, mechanically-operated through a spur or worm gear, or power-operated hydraulically or electrically.

The lubricated plug valve is being used for the following services in the distribution system:

1. Transmission mains.
2. Throttling flow from one service area to another.
3. Domestic water mains.
4. Regulator vaults of high-pressure mains.
5. Pumphouse and regulator stations.
6. Float valves for water storage tanks.
7. Reservoir inlet.
8. Inlet and outlet stop valves at pressure reducing stations.

Depending on the specific installation, the valves range in size from 2-inch through 30-inch, with some ½-inch and 1-inch valves on instrumentation.

In the water treatment plant, lubricated plug valves are being used for the following:

1. Control valves on filter valve control tables.
2. Chemical service lines.
3. Drain lines from sedimentation and clarifications tanks.
4. Drain lines for filter bed wash water.
5. Lines handling deflocculated material.

Probably the two most important reasons for the growing popularity of the lubricated plug valve, to judge by a recent survey of water works in various parts of the country, are ease of operation and positive shut-off (see Table 1). Other reasons given in the survey included: compactness, always operable, adaptability to throttling service, and instantaneous knowledge of open-close position.

The reasons for these advantages will be appreciated with a better understanding of the design and operation of the lubricated plug valve.

Quick Opening and Closing

One of the outstanding features of the plug valve is its quick opening and closing operation. A quarter-turn fully opens or closes the valve. A stop collar on the valve gives positive indication as to the position for open or close. In this way, the operator does not have to rely on the "feel" of a wheel's resistance to tell if the valve is closed.

The valve has three basic components—(a) body, (b) cover, (c) plug—the plug being the only moving member. While the plug is available both in cylindrical and tapered form, the latter is generally the more preferable. The tapered rotary principle makes for simple valve actuation.

A lubricated ground-joint type of shoulder is used in preference to conventional stuffing boxes which operate by gripping around a stem or rod. The shoulder joint is compact, produces a minimum of friction, and combines the functions of stem seal and thrust bearing.

The body design is simple and compact; there are no projecting yokes or bonnets, no exposed threads, and no underhanging body to require room below the pipeline. In most cases, the space occupied by the lubricated plug valve is little more than the diameter of the pipeline flanges. The space economy offered by this type of valve makes it particularly suitable for manifolds, pumphouses or other places where space is at a premium.

Plastic Sealing and Lubrication

It was the development of the pressure-lubrication principle that gave

impetus to widespread application of the plug valve. Pressure lubrication performs three important functions in that it (a) provides "jacking" action, (b) seals the valve, and (c) reduces friction and wear to a minimum.

Lubricant pressure exerts powerful "jacking" action against the smaller end of the valve plug, momentarily unseating it. This action overcomes any adhesion and, because of the taper, creates a small space for a confined lubricant film between the plug and body. As a result, there is a positive means of unseating the valve, without having to use a hammer or wrench.

The usual means of exerting lubricant pressure is an elongated screw, threaded into the outer end of the plug shank. These screws are often provided drilled and fitted with giant "button head" fittings for grease gun lubrication.

Lubricant is distributed around the plug and valve body by means of lubricant grooves, divided between the body and the plug. Placement of grooves is such that the valve can be partly opened or "cracked" without blowing out the lubricant. As a result, even an inexperienced operator can be "turned loose" on the valve.

THIRTY-TWO ½-inch, four-way lubricated plug valves
Installed as control valves on the control tables of the Lincoln, Nebr., filtration plant

Valve Operation

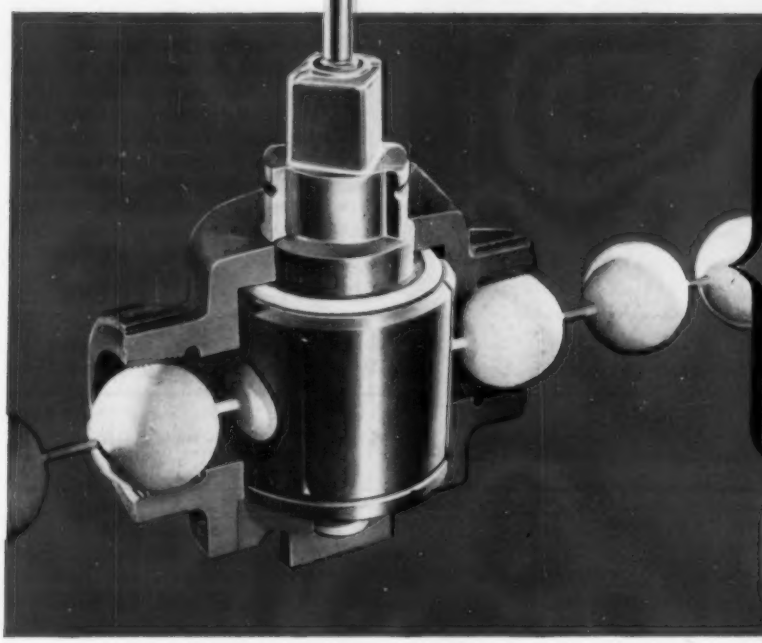
Plug valve accessories are available in a wide variety of forms to allow complete flexibility in method of installation, operation and servicing. Wrenches for hand-operated valves include lever, chain, socket and offset types, and standard electric and pneumatic motor operated units are also available. Valve extensions include turning stem extensions for wrench handle operation, worm gear shaft extensions, watertight gear housing of the road box and sealed top with indicator types, floor stand plant extensions, and elevated gearing or cylinders.

Because of the tapered plug and

PRESSURE-REDUCING vault of Long Beach, Calif., Water Department, showing 8-inch bypass shutoff valve

LUBRICATING 24-inch plug valves regulating discharge flow from Vic Trace Reservoir, Santa Barbara, Calif.

acf Lubricated Plug Valves



ROUND PORT MEANS FREE FLOW ALL THE WAY

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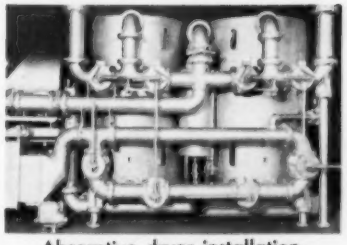

Absorptive dryer installation.

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You get full volume, unrestricted flow throughout the entire piping system when you use acf Round Port Valves.

The pipe-matching port openings cause no loss in head pressure—offer no more resistance to flow than the pipe itself. There are no obstructions—no turbulence and no harmful abrasive effects from solids in suspension. Even the most heavy viscous ladings flow freely through acf Round Port Valves.

Split-second quarter-turn shutoff, non-wedging cylindrical plug, Teflon* head gasket, are additional advantages that add to perfect performance of acf Round Port Valves—that mean extra long trouble-free service—lower maintenance costs and fewer work stoppages.

Act now to step up valve performance—to keep maintenance costs down. Representatives in 50 principal cities.

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W-K-M THROUGH-CONDUIT GATE VALVES

acf LUBRICATED PLUG VALVES

KEY RETURN BENDS AND FITTINGS

lubricant sealed design of these valves, they are not restricted to one-way flow; that is, the valve can be installed in either direction because it holds pressure in either direction. Flow can be reversed at any time without the danger of leakage or jamming.

A common hazard to the life of valve seats is the abrasion caused by dust, dirt and debris in the line. This hazard is entirely eliminated in the lubricated plug valve if proper gland adjustment is maintained. Critical seat areas are fully lubricant sealed, the lubricant being under pressure so that abrasive material cannot intrude. Any dirt or scoring material that may reach the plug is scraped off when the plug is turned back to "open."

Regardless of the line pressure, the plug valve can be relubricated as effectively as with no pressure. Lubricant injection builds hydraulic pressure within the valve to the required degree. In this way the plug can always be effectively lubricated and the jacking chamber under the plug adequately pressurized to permit easy turning. As a result, even if a plug-type lubricated valve is unopened for extended periods of time, it can be easily opened, without difficulties of galling or "freezing."

Maintenance Lubrication

A simple program of periodic lubrication takes a minimum of time and keeps the plug valve in service for the life of the piping. Lubrication practice varies from water works to water works. Some lubricate and test valves monthly; others, every other month, quarterly, semi-annually or annually. Valves that are used very in-

TABLE I
Recent Survey of Lubricated Plug Valves[a] in Water Works[b]

Reply No.	Valves		Type of Service	Lubrication Schedule	Advantages
	No.	Size, in.			
1	10	14, 16, 18, 20	Water lines	Just installed	Smaller head room, hence smaller manhole
2	3	6, 8, 16	Throttling flow from one service to another	Annually	Adaptable to throttling service
3	20	6, 8, 10, 12, 14, 16, 20, 24	Transmission lines	Greased and tested monthly	Ease of operation, better hydraulic features, instantaneous knowledge of position
4	8	6 to 12	Domestic water mains	Semi-annually	Less overall height
5	7	8, 12	Mains where positive shutoff is necessary	Only when used; not operated often	Positive shutoff
6, 7	20	8 to 24	Shutoff and control	Monthly	Easy operation, always operable
8	5	2, 4, 12	Regulator vaults of high-pressure mains	Monthly	Ease of operation; good shutoff
9	20	4 to 8	Booster pump inlet and outlet; reservoir inlet where line is not earth covered	Semi-annually	Complete closing assured; can be closed faster than gate valve
10	16	6, 8, 12, 16, 18, 20,24	Transmission lines, pumphouse, regulator stations	Every other month	Specified where head room is limited; for throttling flows
11	11	16, 20, 24	Distribution mains	Annually	Permit quick shutoff by 1 or 2 men in case of break
12	30	12, 16, 24	Transmission and lateral control	Just installed	Compact; positive closure; nonbinding
13	4	16, 20, 24	Transmission lines	Quarterly	Smooth operation; quick operation by one man
14	53	2, 8, 12, 16, 20, 24	Float valves for water storage tanks; main distribution line; reservoir outlet	Large, semi-annually; small, monthly	Ease of operation; complete shutoff
15	43	½ to 30	Manifolding; main lines; meter testing; bypasses; chemical service	Large, quarterly; meter testing, weekly; others, as needed	Ease of operation; use for throttling service; drop-type closure
16	32	½[c]	Control tables at filter plant	———	———
17	215	1 to 12	Small: shutoff on air and vacuum release valve assemblies on major trunk lines Large: inlet-outlet stop valves at pressure reducing stations	Three times per year	Small: Superior to brass stop cocks previously used because easier to operate and do not leak Large: No chatter in discharge side of regulator under high pressure differentials
18	32	½	Control tables at filter plant	Quarterly	Do not leak

a Nordstrom lubricated plug valves, made by
b All valves are hand-operated except: No. 8, wrench and worm gear.
c 4-way valves.

frequently are often lubricated only when there is occasion to use them.

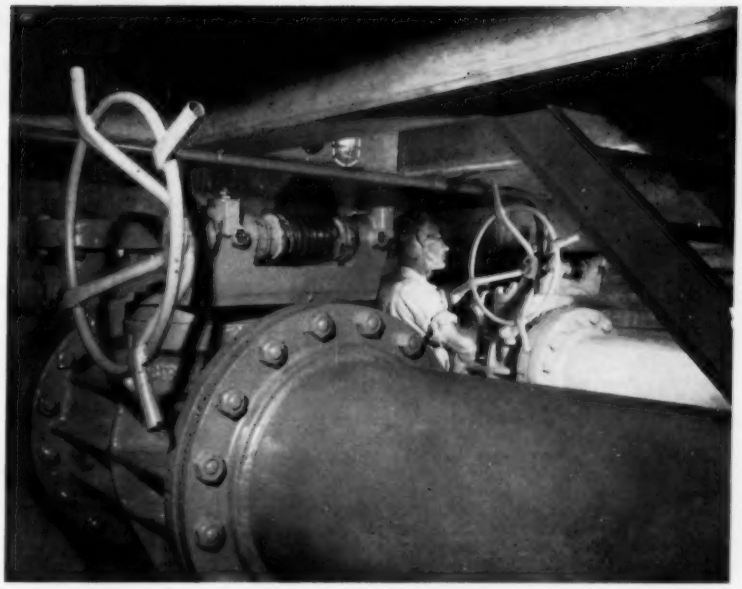
The following are some tips on plug valve servicing that will aid in keeping the valves in top service condition:

1. Plug adjustment should be snug; that is, tight enough to keep the plug from becoming unseated, but not to a degree requiring excessive force to operate the valve.

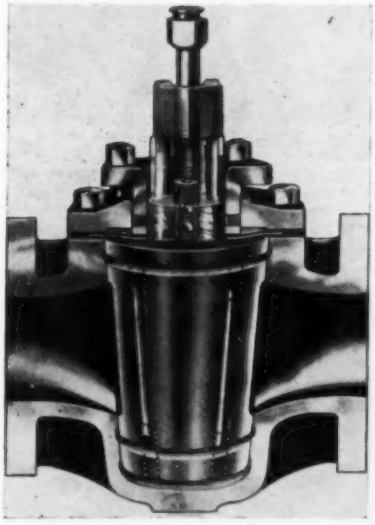
2. Fresh supply of lubricant can be easily forced between the seating surfaces by giving the lubricant screw a few turns. It is important, however, to keep the valve lubricant system filled.

3. Depletion of lubricant in the valve lubrication system will require the addition of several sticks before lubricant can be forced into the seat. Lubricant should be added until increased resistance is felt in turning the lubricant screw, or until there is increased pressure when gun lubrication is used.

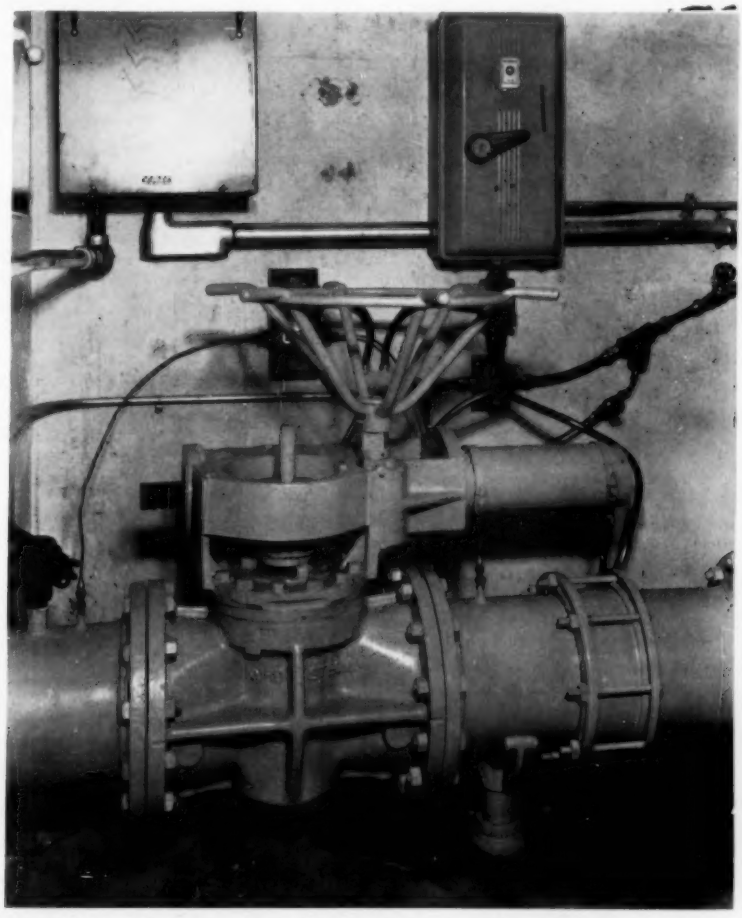
4. The plug should be turned slightly when lubricating, to assist in the distribution of lubricant and to determine if the adjustment is correct. If the valve is lubricated with the adjustment too loose, efficient lubrication cannot be obtained. Further, the valve may be permanently unseated, allowing the lubricant to quickly dissipate and the valve may leak. If the valves are over-lubricated with the adjustment too loose, it can be corrected by alternately tightening the adjustment and turning the plug. This will work out the excess lubricant and permit the plug to return to its proper position in the seat.



LIMITED head room makes worm gear and hand wheel operation advantageous. Foreground (16 in) and (12 inch) background lubricated plug valves in pressure-regulating stations of the Pasadena, Calif., water system



CROSS-SECTION of typical lubricated plug valve



MAIN 12-inch automatic control valve for 1-mg reservoir at LaCanada, Calif.

FIRE HYDRANT FLOW GAGE

A pressure gage with a gpm discharge scale

by A. A. HIRSCH*

State Dept. of Education, Baton Rouge, La.

MEASUREMENT of flow from a fire hydrant is a useful procedure in many ways. Probably the most important application is in evaluation of available fire flows at various sections of a distribution system. Often employed when chlorinating new or repaired mains, a measured withdrawal from a fire plug synchronizes water flow and chlorine feed for uniform mixing. Hydrant flow measurement is also an essential step in the incremental method for determining the C value for a pipe line. When flushing mains through fire hydrants to clear out the distribution system a knowledge of the flow enables an operator to estimate the time required for complete displacement and also to record the amount of water allowed to waste.

Of the several methods in vogue for hydrant flow measurement, namely the special pitot tube-gage combination, the stream trajectory, the short tube with terminal orifice, and the velocity head reading by means of a pressure gage on a closed cap, the last named is the one most generally employed by reason of its simplicity in principal and equipment.

The Procedure

In determining flow from a fire hydrant by the pressure gage method all that is needed is to connect an accurate gage to the closed nozzle, and discharge the hydrant through the other nozzle. The flowing nozzle may be considered as a "short-tube"

Figure 1.—Dial of pressure gage calibrated to read directly fire hydrant flow from a 2½-inch nozzle.

and its flow calculated from the usual orifice formula, but using an orifice coefficient of 0.9 instead of the familiar 0.61 which holds for a sharp edged orifice. Thus

Flow (cu. ft./sec.) = C A V where C = fire hydrant orifice coefficient = 0.9.

*Director, Sectional School on Water Supply and Sewerage.

$$A = \text{area of nozzle (sq. ft.)} = 0.785 \times \frac{\text{Diameter}^2_{\text{(inches)}}}{144} = 0.00545\ \text{Diameter}^2_{\text{(inches)}}$$

$$V = \sqrt{2\ g\ h_{\text{ft. water}}} = \sqrt{2 \times 32.16 \times 2.31 \times \text{Pressure}_{\text{psi.}}}$$ the pressure reading being taken off the closed nozzle

$$= 12.2\sqrt{\text{Pressure}_{\text{psi.}}}$$

Substituting in the first equation:

$$\text{Flow (gpm.)} = 7.48 \times 60 \times 0.9 \times 0.00545\ \text{Diameter}^2 \times 12.2\sqrt{\text{Pressure}_{\text{psi.}}}$$

$$= 27\ \text{Diameter}^2_{\text{(inches)}}\sqrt{\text{Pressure}_{\text{psi.}}}$$

This is the familiar form commonly used to calculate the discharge from a fire hydrant.

Ordinarily the 2½-inch nozzle is used, as the 4- or 4½-inch nozzles do not conform with accuracy to a simple formula. Substituting the value of 2½ inches for the diameter in the above formula there results

$$\text{Flow (gpm. through 2½ in. nozzle)} = 27 \times 2.5^2 \times \sqrt{\text{Pressure}_{\text{psi.}}} = 168.7\sqrt{\text{Pressure}_{\text{psi.}}}$$

from which the discharge through a 2½-inch hydrant nozzle may be conveniently calculated.

The Self-Calculating Gage

Inasmuch as a given velocity head on the pressure gage corresponds to a fixed discharge the gage may be calibrated to read this flow directly and thereby obviate the need for calculation. A dial so calibrated is illustrated in Fig. 1. By marking off a dial in this manner the gage may be used in hydrant flow studies to facilitate discharge adjustments and to enable flow evaluation on the spot without calculations or conversions. Fig. 1 may also be used as an approximate solution to the hydrant formula for a 2½-inch nozzle rather than perform the numerical substitutions.

The accuracy of the pressure gage should be checked on a cold test apparatus, especially in the low pressure range below 500 gpm. where slight inaccuracy causes relatively large errors in the indicated discharge. If the test gage is off the needle position may be reset, the linkage between hollow spring and sector adjusted as required, or a calibration curve drawn to show the true pressure corresponding to any gage reading. From Fig. 1 it will be noted that below a flow of about 250 gpm. the type of pressure gage as illustrated is inapplicable since it fails to deflect.

For flows below this lower limit the discharge is measured by such methods as (1) large water meter, (2) the time required to fill a barrel through a short section of hose, (3) a more sensitive gage or manometer, (4) a special hydrant nozzle with terminal sharp-edged orifice, or (5) measuring the offset distance from the barrel to a point where the stream has dropped one foot, and referring to a calibration curve.

Some Relationships Between Current Flow and Heat Production

One Kilowatt
= 56.92 B.T.U. per min.
= 1.34 horse-power.

One B.T.U. per Min.
= 0.01757 KW.
= 0.02356 H.P.

One Horse Power
= 42.44 B.T.U. per min.
= 0.7457 KW.

One Horse Power/Hour
= 2,547 B.T.U.
= 0.7457 KW.H.

One Kilowatt/Hour
= 3.415 B.T.U.
= 80.46 H.P.

M & H VALVE AND FITTINGS COMPANY

ANNISTON, ALABAMA

The letters M & H are the sign of quality on Valves, Hydrants and Pipe Line accessories. High quality materials, simplicity of design and expert workmanship have established for M & H enviable reputation for dependable service in the water works and sewage fields and for industrial uses. M & H products are modern in design, with many exclusive M & H features.

M & H VALVES AND FIRE HYDRANTS

M & H A.W.W.A. Gate Valves are furnished double disc parallel seat, or solid wedge, iron body, bronze mounted, non-rising stem, or outside screw and yoke. Available spur or bevel geared and with enclosed grease case, also hydraulically or electrically operated. Sizes 2" to 36". Low Pressure and High Pressure Valves and Square Bottom Valves are an established part of the M & H line.

M & H Compression Type Hydrants conform to latest specifications of the American Water Works Association. They are available either in standard, flush type or traffic models. Hydrants with 5¼" and 6¼" valve opening are listed and approved by Underwriters Laboratories of Chicago and Associated Factory Mutuals of Boston and A.W.W.A. Hydrants with 4¼" and 4½" valve opening are A.W.W.A. approved only.

Outstanding features include dry top, easy to lubricate, revolving head. Can be lengthened and working parts completely removed without digging up hydrant.

FILTER PLANTS & SEWAGE PLANTS

Hydraulically and electrically operated M & H Valves are used in sewage treatment plants, water works, filter plants, etc., to save time and labor since these valves can be operated by remote control for quick, easy closing or opening. They are also used as emergency valves to admit higher water pressures into the mains in case of fire. Sizes 2" to 36" A.W.W.A.

M & H Flap Valves and Shear Gates are iron body, bronze mounted, used in Filtration and Sewage Disposal Plants.

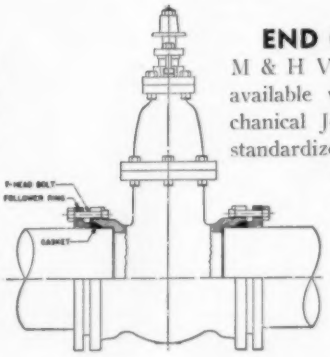
Hydraulic Gate Valve

Low Pressure Gate Valve Rising Stem

Low Pressure Gate Valve Non-Rising Stem

END CONNECTIONS

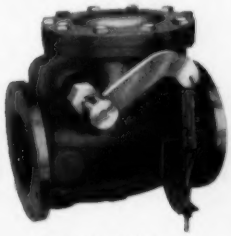
M & H Valves and Hydrants are available with Standardized Mechanical Joint ends for use with standardized mechanical joint cast iron pipe, also with hub ends, flanged, Ring-Tite and Universal ends.



FIRE PROTECTION

M & H makes a complete line of valves, hydrants, indicator posts and underground pipe fittings for fire protection water systems. All of these M & H products are approved and listed by the National Board of Fire Underwriters of Chicago and by the Associated Factory Mutuals of Boston. All castings therefore are marked "UA—FM."

Rising Stem Gate Valve

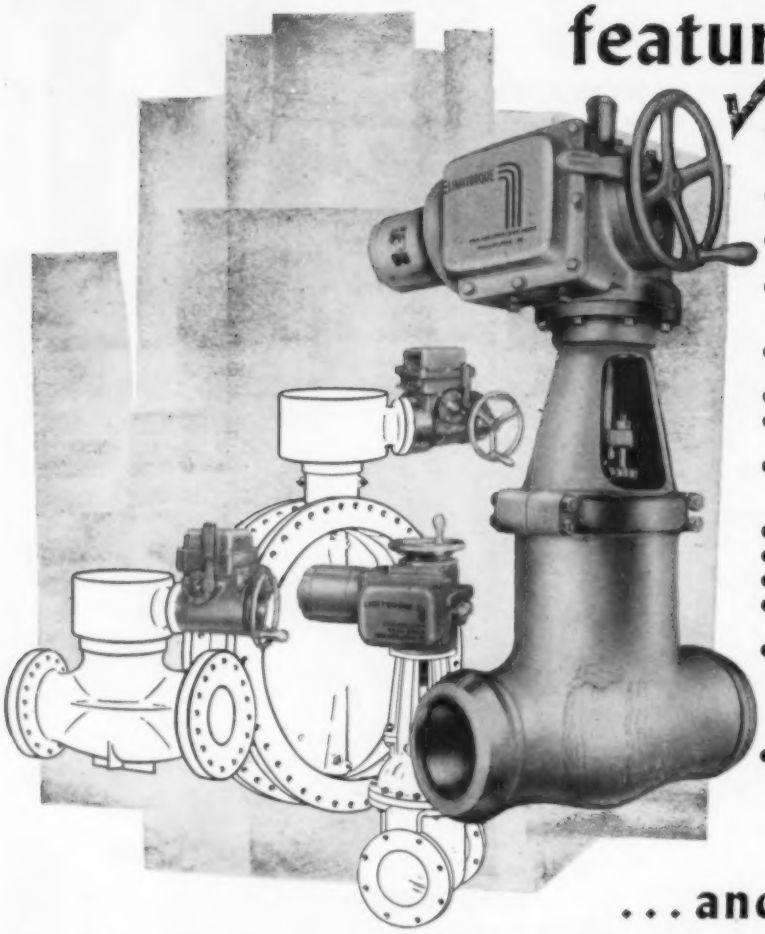

Spring Check Valve

Indicator Post

M & H PRODUCTS INCLUDE:

WALL CASTINGS	FLANGED FITTINGS	TAPPING SLEEVES AND VALVES
CHECK VALVES	FLOOR STANDS	SPRING LEVER CHECK VALVES
EXTENSION STEMS	SHEAR GATES	MUD VALVES
FLAP VALVES	B & S FITTINGS	FLANGE AND FLARE FITTINGS
	CUTTING-IN TEES	

Check these features



- Micrometer torque seating switch gives tight valve closure, and protects valve parts from damage.
- Self contained unit—no gears, stem nut or bearings to buy.
- Weatherproof, dust-tight, watertight and explosion-proof construction.
- Hammerblow device . . allows motor to reach full speed, before load is engaged.
- Non-rotating handwheel built into the unit.
- Automatic declutching.
- Motor is disengaged during handwheel operation.
- Can always be declutched for handwheel operation regardless of weather or electrical conditions.
- High torque motors.
- Simple valve yoke.
- May be mounted in any position.
- Three to four times faster handwheel operation.
- Actuation may be by any available power source such as electricity, air, oil, gas, water or steam. LimiTorque is readily adapted for microwave control.
- LimiTorque is designed for plug, butterfly, gate and globe valves up to 96″ diameter . . . Entire Unit and nut can be lifted off valve yoke, by removing flange bolts.

. . . and you'll understand why more *LIMITORQUE* valve controls are in use than all others combined

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Maintenance of Steel Water Works Tanks*

A symposium of papers presented before the New England Water Works Assn.

Specifications

by GEORGE A. SAMPSON

Weston & Sampson, Cons. Engrs. Boston, Mass.

As an introduction to the problem of maintenance of steel waterworks tanks, the speaker will first list the specifications and recommended practices available in printed form and then briefly summarize the conclusions contained in these documents.

The Amer. Water Works Assn. Journal for November, 1935, contains specifications entitled "Standard Specifications for Riveted Steel Elevated Tanks and Standpipes", prepared by a committee of that association. Following the advent of welding construction, a joint committee of the AWWA and the Amer. Welding Society revised these specifications to include welding and they were approved by the New England Water Works Association on September 24, 1942.

In October, 1944, the NEWWA appointed a committee on "Steel Standpipes and Elevated Tanks", to serve as a joint standing committee with representatives of the AWWA and the AWS. This joint committee proceeded to revise the 1942 specifications and the revisions were approved by the NEWWA on September 14, 1948. These revised specifications were entitled "Standard Specifications for Elevated Steel Water Tanks, Standpipes, and Reservoirs" and were Published in the Jan. NEWWA in December 1948. The committee also prepared separate recommendations for repairing and repainting existing tanks, as distinguished from new tanks, under the title, "Tentative Recommended Practice for Inspecting, Repairing and Repainting Elevated Steel Water Storage Tanks, Standpipes and Reservoirs". This document was also approved by the NEWWA on September 14, 1948, and published in the Jour. NEWWA in Dec. 1948.

After further study, the joint committee revised the 1948 specifications under the following three separate headings: "Standard Specifications for Elevated Steel Water Tanks, Standpipes and Reservoirs"; Tentative Recommended Practice for Inspecting and Repairing Elevated Steel Water Storage Tanks, Standpipes and Reservoirs"; and "Painting and Repainting Elevated Steel Water Storage Tanks, Standpipes and Reservoirs". These three specifications were approved by the NEWWA on March 20, 1952, and the painting specification was published in the Jour. NEWWA in Dec. 1952. The specifications have been printed in pamphlet form by the AWWA as D 100-52, D 101-52 and D 101-52, respectively, and are available for a nominal price at 2 Park Ave., New York 16, N.Y.

The proper maintenance of a steel water tank is concerned with periodic inspections, to determine the condition of the tank, repairs as needed to keep the tank structurally intact, and painting to protect the steel. Tanks need repainting frequently, but, if properly maintained, repairs are rarely necessary.

Inspection

Every steel water tank should be carefully inspected when leakage or other apparent deterioration is observed as well as before repainting. In any event, all water tanks should be inspected at intervals of not more than five years. The owner should have a disinterested inspector examine the metal surfaces inside and outside to determine the condition of the paint and metal, in order to decide what repairs, if any, are needed and what painting should be done. At the same time the owner should invite any contractors whom he wishes to bid on the work to inspect the tank and familiarize themselves with the actual conditions. The tank should be emptied and the inside surfaces thoroughly cleaned for the inspection. The owner should draw up proposals for the work to be done, covering any repairs, method of cleaning the steel, the kinds of inside and outside paint to be used, number of coats and other details.

Repairs

The owner, using the inspector's report as a guide, should define and list the repairs to be made. Contractors should be asked to submit bids on a fixed lump-sum or unit-price basis. The owner should itemize repair work by units, such as the number of rivets to be replaced, caulked or welded, the lineal feet of seams to be caulked or welded, the number of pits to be filled, any parts to be replaced, and so forth. All welding should be performed in accordance with the welding provisions given in AWWA-NEWWA-AWS "Standard Specifications for Elevated Steel Water Tanks, Standpipes and Reservoirs", AWWA D 100-52.

All repairs shall be neatly done by experienced workmen using equipment best adapted to the work. Upon completion of the repair work the tank shall be watertight.

Cleaning Steel Before Painting

The methods favored for removing the mill scale from plates and structural shapes in the shop before applying a priming coat of paint are sand- or grit-blasting and pickling. If the purchaser specifies that mill scale be removed and if pickling or blasting is not specified, it shall be understood that only loose mill scale and rust be removed by wire-brushing, or the plates and structural shapes may be dehydrated in the shop with an oxy-acetylene torch, removing such mill scale as becomes loosened with one application of the torch followed by wire brushing, after which the priming coat shall be applied while the parts are still warm.

Paints

The committee's recommendations for paints and methods of painting are necessarily rather general in

*Reprinted by permission from the Journal of the New England Water Works Assn.

CHICAGO BRIDGE & IRON COMPANY

Since 1893, Chicago Bridge & Iron Company has been designing, fabricating and erecting elevated steel tanks and many other types of steel plate work for municipal water systems throughout the country. These 62 years have been years of progress. They have given us a vast background of experience which has led to structural improvements, better workmanship and efficient erection methods. Tank designs have been constantly improved to provide today's pleasing, streamlined structures.

Tanks for municipal service are built by Chicago Bridge & Iron Company in accordance with specifications of the American Water Works Association. Four strategically located plants in Birmingham, Chicago, Salt Lake City and Greenville, Pennsylvania are always ready to serve you.

ELEVATED WATER TANKS

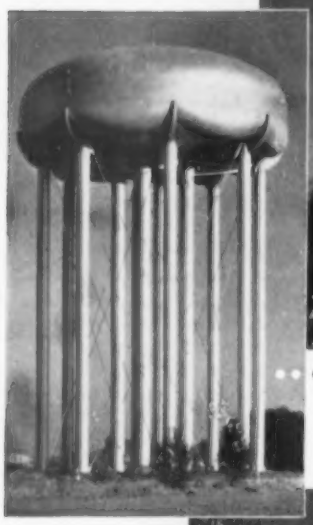
Horton elevated water tanks are designed to provide dependable gravity pressure in water distribution systems. They usually reduce pressure variations in the mains and often cut down pumping costs.

Horton elevated water tanks are built in five basic types—ellipsoidal-bottom tanks, radial-cone bottom tanks, Waterspheres, Waterspheroids and Hortonspheroidal tanks. We shall be pleased to submit estimating figures or quotations on any of them. When writing please state capacity, height to bottom, range in head, location and shape or design desired. There is no obligation on your part.

WATERSPHERES

The smooth, streamlined Watersphere presents a pleasing appearance. All piping connections and ladders are located inside the supporting column to which access is provided by a door at ground level. The lower portion of the supporting column may also be used as a pumphouse.

Capacity in Gallons	Diameter of Sphere
25,000	19'4"
30,000	20'4"
40,000	22'4"
50,000	24'0"
60,000	25'6"
75,000	27'4"
100,000	30'0"
150,000	34'0"
200,000	37'6"
250,000	40'6"



ELLIPSOIDAL-BOTTOM WATER TANKS

Ellipsoidal-bottom elevated tanks are relatively large diameter and shallow depth. Unless otherwise specified, they are built with cylindrical columns and ellipsoidal roofs.

Gallons Capacity	Tank Dimensions	
	Diameter	Range
50,000	22'0"	19'0"
60,000	24'0"	19'0"
75,000	26'0"	21'0"
100,000	28'0"	24'0"
125,000	30'0"	25'6"
150,000	32'0"	27'6"
200,000	36'0"	29'6"
250,000	40'0"	29'0"
300,000	43'0"	30'0"
400,000	46'0"	35'0"
500,000	50'0"	37'6"

HORTONSPHEROIDAL WATER TANKS

Hortonspheroidal elevated tanks are modern, attractive structures. They are built in standard capacities of 1,000,000 to 3,000,000 gallons and are supported either on two rings of cylindrical columns or one ring of cylindrical columns and a large central riser.

Gallons Capacity	Tank Dimensions	
	Diameter	Range
1,000,000	87'6"	25'
1,000,000	81'0"	30'
1,500,000	92'0"	35'
2,000,000	106'0"	35'
2,500,000	117'0"	35'
3,000,000	120'0"	40'

RADIAL-CONE BOTTOM WATER TANKS

A functional design that permits large capacity water tanks to be built with a relatively low range in head. They are pleasing in appearance and easy to maintain.

Gallons Capacity	Tank Dimensions	
	Diameter	Range
500,000	60'4"	25'
750,000	74'3"	25'
750,000	67'6"	30'
1,000,000	86'0"	25'
1,000,000	78'0"	30'
1,000,000	71'6"	35'
1,500,000	104'0"	25'
1,500,000	96'0"	30'
1,500,000	88'0"	35'
2,000,000	112'0"	30'
2,000,000	102'0"	35'
2,500,000	114'0"	35'
3,000,000	117'0"	40'

CHICAGO BRIDGE & IRON COMPANY

WELDED STEEL RESERVOIRS . . .

C B & I builds welded steel reservoirs and standpipes in standard capacities up to 10,000,000 gals. and in special designs to specified capacities. Careful fabrication and erection assures long service life. Welded construction results in smooth tank surfaces simplifying maintenance.

Chicago Bridge & Iron has designed, fabricated and erected all types of heavy steel plate work for water and sewage plants throughout the country. When requesting quotations, we would appreciate receiving plans and specifications.

HORTONSPHERES FOR DIGESTER GAS . . . . . .

Hortonspheres® provide an economical means of storing sewage plant gas under pressure, and thus permit the gas produced in digesters to be utilized effectively. When the *supply* of digester gas exceeds demand, the surplus is pumped into the Hortonsphere. When the *demand* exceeds the supply, gas flows from the Hortonsphere to make up the difference. The entire shell of the Hortonsphere is accessible for inspection and painting. Hortonspheres are built in sizes up to 1,500,000 cu. ft.

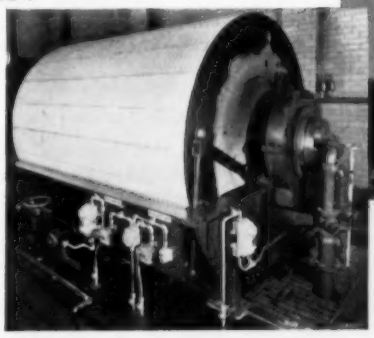
PHOSPHORIC ACID PROCESS PICKLING AND PAINTING

The Horton® phosphoric acid process saves maintenance dollars and prolongs the life of steel plate structures. It removes mill scale before shipment from our plants and helps provide a better bond between the prime coat of paint and the steel.

WATERSPHEROID . . . . . .

The modern, streamlined Waterspheroid® was designed to combine beauty and service. An elevated water storage tank provides a dependable gravity pressure water supply in a functional, pleasing "package". Horton Waterspheroids are built in standard capacities of 300,000, 400,000 and 500,000 gals.

CONKEY SLUDGE FILTERS . . . . . .



Over 2,000 tons of various sludges and industrial wastes (primary—elutriated digested—bio-chemical—industrial) are daily dewatered on Conkey Sludge Filters. Every municipal and consulting engineer should be acquainted with the advantages and trouble-free performance of Conkey equipment, fabricated by CB&I.

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Detroit 26.....1536 Lafayette Bldg.
Houston 2.....2142 C&I Life Bldg.
New York 6.....3316—165 Broadway
Philadelphia 3.....1648—1700 Walnut St.
Pittsburgh 19.....3260 Alcoa Bldg.
Salt Lake City 4..550 West 17th South St.
San Francisco 4.....1525—200 Bush St.
Seattle 1.....1330 Henry Bldg.
South Pasadena.....712 Fair Oaks Ave.
Tulsa 3.....1841 Hunt Bldg.

In Canada: HORTON STEEL WORKS, LIMITED, FORT ERIE, ONTARIO

character, leaving the details to be set forth in the owner's specifications, which should describe the method of cleaning the steel, the kinds of paints, the number of coats both inside and outside. The specifications recognize that various types and kinds of paint have demonstrated their suitability and that no type or kind is universally applicable.

In repainting old tanks, if the paint is in good condition and adheres tightly to the steel, it may be left on. All rust, loose mill scale and loose paint should be removed by means of sand- or grit-blasting, power-driven scaling tools, scrapers and wire brushes (preferably power-driven), emery cloth or sand paper in either air or cloth dusters. When cleaned by sand- or grit-blasting, the equipment should have ample capacity to furnish the required volume of compressed air to operate the blast effectively. If sand is used, it should be principally composed of silica grains and as coarse as is practicable to use. Special care should be used to clean around rivet heads, along seams and in pits. Whenever metal is cleaned by blasting on any day, it should be coated with a primer on the same day. If rust forms on any blasted surface, the surface should be re-cleaned and wiped free of dust before applying the primer. The metal should be completely dry before applying any paint.

The shop priming coat should be an inhibitive paint on all surfaces inside and outside, except on contect surfaces and along edges to be welded. It is important that the primer be compatible with field coats of paint and desirable that the shop and field coats be made by the same manufacturer, to avoid subsequent irresponsibility.

The following paints are suggested:

Inside Surfaces

a. Red lead and linseed oil primer, conforming to Federal Specifications TT-P-86a, Type I, with the addition of 2 lb per gallon of dry litharge, to be added shortly before application, to speed up the drying. The paint shall set to touch in not more than 6 hours and dry through in not more than 24 hours. Each coat of paint shall dry for at least 24 hours before applying subsequent coats and the final coat shall dry at least 48 hours before the tank is filled with water. The paint shall show no curdling, caking or color separation and shall be free from lumps and skins. The paint shall brush easily and show no running or sagging tendencies when applied to smooth vertical surfaces. The paint, when reduced with not more than 1 part by volume of mineral spirits (conforming to Federal Specifications TT-T-291, Grade 1) to 8 parts by volume of paint, shall spray satisfactorily in all respects. The paint shall dry to a smooth uniform finish, free from roughness, unevenness or other surface imperfections.

b. Red lead phenolic resin varnish paint when used as a primer, is suitable only on thoroughly cleaned surfaces obtained by pickling or blasting. For finish coats, it is suitable for surfaces cleaned by wire brushing. This paint should conform to Federal Specifications TT-P-86a, Type IV. The general properties as to brushing and spraying are similar to red lead and linseed oil paint. One difference is in a considerably quicker drying period, which has the advantage of being able to speed up the time required to fill the tank with water after it is drained for painting.

c. Hot-applied coal-tar enamel priming and coating materials shall meet the requirements of the latest revision of A.W.W.A. C 203 and C 204, standard specifications for coal-tar enamel protective coatings for steel water pipe.

d. Cold-applied coal-tar paint, prepared from coal-tar pitch, mineral filler and solvent, designated as CA-50, does not have the durability of hot-applied coal-tar enamel, but can be applied by brushing or spraying and can withstand cold temperatures better than hot-applied enamel. A minimum of three coats should be applied. This coating is not suitable for use in open-top tanks which would expose the coating to direct sunlight.

e. Wax-grease coatings may be either of the cold-application type or of the type adapted for hot application.

Outside Surfaces

a. Red lead and linseed oil paint is suitable for the outside priming and finish coats. The specifications are similar to those for inside surfaces, except no litharge is added. The drying period for each coat is set to touch in not more than 6 hours and dry through in not more than 36 hours. Each coat of paint shall dry for at least 36 hours before applying subsequent coats.

b. Red lead phenolic resin varnish paint when used as a primer or finish coat on outside surfaces should follow the recommendations for similar paint on inside surfaces.

c. White linseed oil chalking or non-chalking type finish paint shall conform to Federal Specification TT-P-102, Class A and Class B, respectively. They are titanium, lead, zinc and oil exterior ready mixed white paints. The maximum drying tim is 18 hours. The non-chalking typ is usually tinted in light colors.

d. Black linseed oil finish paint shall conform to Federal Specifications TT-P-61a. It is a carbon, red lead, mineral-extender and, if desired, iron oxide, linseed oil paint. The maximum drying time is 18 hours.

e. Aluminum finish paint shall consist of a varnish conforming to Federal Specifications TT-V-81b, Type II, Class B, and an aluminum pigment powder and paste conforming to Federal Specifications TT-A-468a, Type II, Class B. The maximum drying time is 18 hours.

f. Foliage green, linseed oil paint, in accordance with the formula used by the State of Maine Highway Commission, Bridge Division, is also suggested. The formula is given in the specifications. The maximum drying time is 20 hours.

Paints should be delivered in the original containers, marked with the name of the manufacturer, type and quantity. The various coats should have enough difference in color so that each successive coat will be properly covered. It is suggested that the final outside coat be from the same manufacturer's batch for uniformity in color.

Electric (cathodic) protection has frequently been used for protecting water-tank interiors below the flow line with satisfactory results when properly installed and maintained. Some difficulties have been encountered in cold climates and when the water is a poor conductor of electricity. For installations in new tanks, it is recommended that all submerged steel surfaces be painted, as by its electrical resistance, the paint reduces current requirements.

Painting

For new tanks the field coats follow the erection and testing for leakage, when water is available. For tanks that have received a shop priming coat, the exposed, unpainted interior and exterior surfaces should be wire brushed, wiped clean and given a spot coat of the same inhibitive primer as used in the shop, followed by the number of coats of paint of the make, types, and colors specified by the purchaser. For tanks without a shop coat, the mill scale should be removed by blasting or by

power wire-brushing if loose from weathering.

For new or old tanks, surfaces should be painted immediately after cleaning. Surfaces should be thoroughly dry before painting and a sufficient interval should elapse between coats for the undercoat to harden properly. No painting should be done when the temperature is less than 40°F. and no paint should be applied during wet or foggy weather, or upon metal coated with frost. Painting should be done only by experienced workmen.

The two general methods of applying red lead or similar paints are brushing and spraying. More recently, rollers have been used for welded tanks with apparently good results.

If the paint is applied by brushing, each coat should be brushed on in one direction and then smoothed in the opposite direction, to produce a complete coverage of a uniform thickness.

If applied by spraying, suitable nozzles should be used and the air pressure on the container and atomizer should be within the proper range for good work. Care should be taken to prevent paint spatters on adjacent buildings or property, by spraying only on quiet days and when the wind is in a favorable direction.

Coal-tar enamels are applied in two coats. The primer should be evenly and carefully applied to avoid runs, festoons or other heavy accumulations. No coal-tar primer should be applied when the temperature of the steel is below 45°F., or when there is any moisture on the steel. After the primer is dry for two or three days, the final coat is a hot coal-tar enamel, applied with daubers. The pieces of coal-tar enamel should be heated in a suitable melting kettle with an adjustable intensity of flame, to maintain the temperature recommended by the manufacturer. The enamel as drawn from the melting kettle should be poured through a fine wire screen, to remove any foreign substances.

Cold-applied coal-tar paint appears in the container as a heavy bodied paste-like material, which by stirring becomes liquid enough for painting. The first coat, applied directly to the steel without a primer, is usually brushed; subsequent coats are applied by brushing or spraying with pump-type equipment.

Wax-grease paints applied cold shall be thoroughly rubber onto the clean dry metal with a stubby brush. The thickness of the coating shall be not less than 0.02 inch and not more than 0.03 inch. The tank can be placed in service as soon as the coating is complete.

Wax-grease paints applied hot shall be applied to the clean dry metal by means of a spray apparatus, utilizing fluid pressure through special nozzles. The temperature of the coating shall be not less than 250°F. and not more than 300°F. After application the coating should be thoroughly flamed with a torch, to smooth out all laps and close any pinholes. The thickness of the coating shall be not less than 0.03 inch and not more than 0.06 inch.

Ventilation

Adequate ventilation must be provided while painting or coating the interior surface of a tank, especially with coal-tar products and some volatile paints. It is sometimes necessary to provide forced-air ventilation.

Cleanliness

All the operations of erecting, repairing and painting potable-water tanks should be conducted in a sanitary manner. No person shall be permitted to work in a tank if he has a malignant illness within a period of 7 days prior to entering the tank. The purchaser shall have the right to engage a physician to judge whether any person is unfit to work in the tank.

The owner shall assure himself by a careful inspection that the interior of the tank is clean and sanitary befor it is placed in service. In addition, it is recommended that the tank should be disinfected. For this purpose chlorine is usually used. A common method is to scatter high-test calcium hypochlorite (H.T.H.), either as a powder or liquid solution, over the bottom of the tank as it is filled with water, so as to provide a concentration of 50 ppm of chlorine in the full tank. Sometimes a lesser concentration is used when the chance of contamination is negligible. After the tank is filled, it should stand 24 hours if possible, but for not less than 6 hours, depending on whether any pollution may be protected by films or particles.

The tank should then be completely drained to waste and refilled from the regular source of supply. After filling, a sample of water should be collected and analyzed, to determine whether the tank may be safely placed in service.

The Superintendents' Problems

by ALLEN M. SYMONDS

Engineer, General Engineering & Construction Co., Boston, Mass.

THE AVERAGE water-works superintendent is employed in an occupation which is very much diversified. To cover all phases of his work he should be a construction engineer, a mechanic, an office manager, a public-relations expert, an orator and a steeple-jack. Most of us make out fairly well with all of these phases except the last one. If a pump breaks down or a pipe springs a leak or a customer argues about a water bill, we have in each case something tangible to work on or throw out the office door, as the case may be. When it comes to a standpipe or elevated tank we have have something different. In my experience I do not know a single water-works man who will climb to the top of a 100-foot tank.

Interruption of Fire Service

Another important factor having to do with the maintenance of water tanks is that many averaged-sized towns depend upon a single tank to furnish fire protection, with the result that there is a serious fire hazard when the tank is taken out of use. This is a responsibility which the water-works superintendent does not like, but must accept when he makes plans to paint his tank.

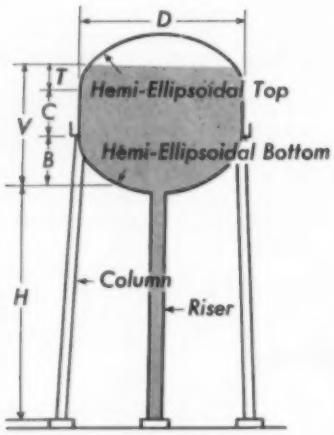
Speaking from the standpoint of a private water company I have often wondered as to the legal liability in case of a damaging fire, with little or no water available because of the water tank's being voluntarily taken out of service. In my experience I have not encountered any damage suit because of these conditions, but I can visualize my feelings if I happened to find myself on the short end, unprotected, and the result was the loss of a home. Such thoughts

Capacities and Sizes of

STANDARD ELEVATED STEEL TANKS

by PITTSBURGH · DES MOINES

In these compact but complete tables, data are furnished on the various types of elevated steel tanks, and on steel reservoirs. For full information as to the application of these tanks, for designs, for specifications, or for estimates, write—without obligation to our nearest office.



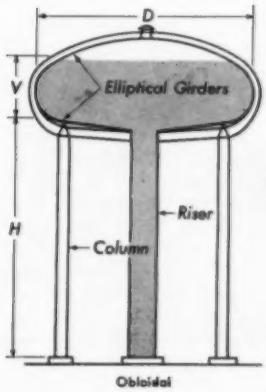
Double Ellipsoidal

TABLE I—DOUBLE ELLIPSOIDAL TANKS

Capacity U.S. Gallons	Tank Dimensions					Balcony Width	Number of Columns	Radial Bevel of Columns	Tower Height H
	D	V	B	C	T				
25,000	18'0"	14'4⅜"	4'9"	6'0¼"	3'7½"	24"	4	1:12	see note**
30,000	18'0"	17'0"	4'9"	8'7¾"	3'7¼"	"	"	"	"
40,000	20'0"	18'6⅜"	5'2⅜"	9'4¼"	4'0"	"	"	"	"
50,000	22'0"	19'2½"	5'11"	8'10¾"	4'4⅜"	"	"	"	"
50,000	24'0"	16'8⅛"	6'4⅛"	5'6⅜"	4'9⅝"	"	"	"	"
60,000	24'0"	19'7½"	6'4⅛"	8'5⅜"	4'9⅝"	"	"	"	"
75,000	26'0"	21'2⅛"	6'10½"	9'1¼"	5'2⅜"	"	"	"	"
100,000	28'0"	23'8⅜"	8'7"	9'6½"	5'7¼"	"	"	"	"
100,000	30'0"	21'0⅞"	8'11"	6'1⅞"	6'0"	"	"	"	"
150,000	32'0"	27'4"	9'4½"	11'7"	6'4⅜"	"	"	"	"
150,000	34'0"	24'9⅜"	9'10½"	8'1⅜"	6'9⅝"	"	"	"	"
200,000	36'0"	29'4½"	10'6⅛"	11'8"	7'2⅜"	"	"	"	"
250,000	38'0"	33'0"	11'3⅝"	14'3⅜"	7'4⅞"	30"	6	1:20	"
250,000	40'0"	30'10½"	11'10⅛"	8'6"	10'6"	"	"	"	"
300,000	44'0"	30'9"	13'0½"	7'11⅜"	9'8⅝"	"	"	"	"
400,000	48'0"	34'3⅜"	14'7"	11'0"	8'8⅜"	"	"	"	"
500,000	50'0"	39'0⅞"	15'6⅜"	15'5⅜"	8'0⅜"	"	8	"	"
500,000	55'0"	29'11"	12'0"	10'11"	7'0"	"	"	Vertical*	"
600,000	50'0"	45'10½"	15'6⅜"	22'3¼"	8'0⅜"	"	"	1:20	"
750,000	60'0"	41'7⅝"	18'0"	11'10⅜"	11'9"	"	"	Vertical*	"
750,000	65'0"	37'0⅜"	20'1⅜"	6'5"	10'5½"	"	"	"	"
1,000,000	65'0"	47'1¼"	20'1⅜"	16'5⅞"	10'5½"	"	10	"	"
1,000,000	70'0"	42'6½"	23'0"	10'9½"	8'9"	"	"	"	"
1,000,000	75'0"	35'0"	20'6"	8'6"	6'0"	"	"	"	"
1,250,000	70'0"	51'2⅜"	23'0"	19'5¾"	8'9"	"	12	"	"
1,500,000	70'0"	59'10⅞"	23'0"	28'1⅞"	8'9"	"	"	"	"

* Standard practice is to make columns vertical for Double Ellipsoidal Tanks whose diameter exceeds 50 ft. However, their columns may be inclined if desired, in which case their radial bevel would be 1:20.

** Standard tower heights (H) are as follows:
Up to 50 ft. in even 2 ft. intervals,
from 50 ft. to 100 ft. in even 5 ft. intervals,
and over 100 ft. in even 10 ft. intervals.
Most common standard tower heights are 75 ft. and 100 ft.



Obloidal

TABLE II—OBLOIDAL TANKS

CAPACITY U.S. GALLONS	DIAMETER D	HEAD RANGE V	TOWER HEIGHT H
1,000,000	88' 0"	25' 0"	As Required
1,500,000	92' 0"	35' 0"	" "
2,000,000	106' 0"	35' 0"	" "

PDM
WATER STORAGE TANKS

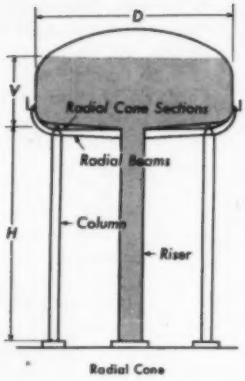


TABLE III—RADIAL CONE BOTTOM TANKS

CAPACITY U.S. GALLONS	TANK DIMENSIONS D	V	NUMBER OF COLUMNS	TOWER HEIGHT H
300,000	53′ 0″	20′ 0″	8	As Required
500,000	60′ 0″	25′ 0″	"	" "
750,000	73′ 0″	25′ 0″	"	" "
750,000	67′ 0″	30′ 0″	"	" "
1,000,000	85′ 0″	25′ 0″	10	" "
1,000,000	77′ 0″	30′ 0″	"	" "
1,000,000	71′ 0″	35′ 0″	"	" "
1,250,000	95′ 0″	25′ 0″	12	" "
1,250,000	87′ 0″	30′ 0″	"	" "
1,250,000	80′ 0″	35′ 0″	"	" "
1,250,000	74′ 0″	40′ 0″	"	" "
1,500,000	103′ 6″	25′ 0″	"	" "
1,500,000	95′ 0″	30′ 0″	"	" "
1,500,000	88′ 0″	35′ 0″	"	" "
1,500,000	81′ 6″	40′ 0″	"	" "
2,000,000	108′ 6″	30′ 0″	16	" "
2,000,000	101′ 0″	35′ 0″	"	" "
2,000,000	94′ 0″	40′ 0″	"	" "
2,500,000	121′ 6″	30′ 0″	"	" "
2,500,000	112′ 0″	35′ 0″	"	" "
2,500,000	105′ 0″	40′ 0″	"	" "
3,000,000	123′ 6″	35′ 0″	20	" "

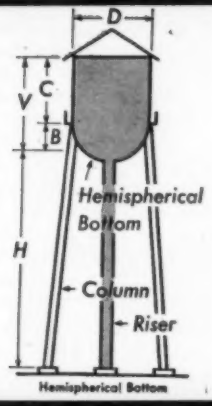


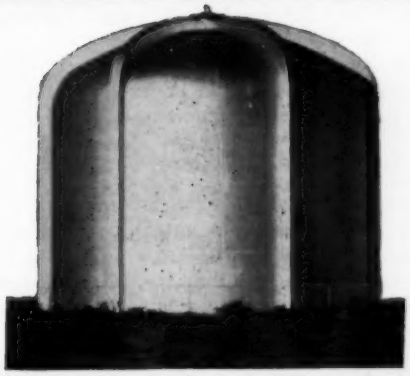
TABLE IV—HEMISPHERICAL BOTTOM TANKS

Capacity in U.S. Gallons	Tank Dimensions D	V	B	C*	No.** of Columns	Balcony Width	Tower Height H
25,000	15′0″	19′10½″	5′4″	14′ 6½″	4	18″	
30,000	15′0″	23′ 8¼″	5′4″	18′ 4¼″	4	18″	
40,000	17′0″	24′11¼″	6′8″	18′ 3¼″	4	24″	
50,000	19′0″	25′ 6″	8′0″	17′ 6″	4	24″	As Required
60,000	19′0″	30′ 3½″	8′0″	22′ 3½″	4	24″	
75,000	21′0″	30′ 6¼″	8′0″	22′ 6¼″	4	24″	

* This column lists height of tank cylinder up to high water level. The cylinder actually extends 3" higher.
** Radial bevel of columns of 4 column towers is 1-½:12; of 6 column towers 1:10.

TABLE V—STEEL RESERVOIRS

Capacity in U. S. Gallons	Diameter	Height
50,000	20′	21′ 6″
60,000	22′	21′ 6″
75,000	24′	22′ 6″
100,000	26′	25′ 6″
150,000	30′	28′ 9″
200,000	34′	29′ 9″
250,000	38′	29′ 9″
300,000	42′	29′ 3″
400,000	46′	32′ 6″
500,000	50′	34′ 6″
750,000	60′	35′ 9″
1,000,000	70′	35′ 0″
1,500,000	80′	40′ 3″
2,000,000	95′	38′ 3″
2,500,000	110′	35′ 6″
3,000,000	120′	35′ 9″
4,000,000	130′	40′ 9″



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sometimes make you wonder whether or not the risk is worth while.

Because of these problems water-tank maintenance is often neglected or deferred to some future date.

Confidence in Contractor

Due to the fact that climbing over and around tanks is a specialized occupation, performed only by steeple-jacks, the water-works superintendent is very much at the mercy of a contractor who may be awarded the maintenance work. For this reason, it is extremely important that he choose only a proven and reliable firm and co-operate with them to the fullest possible extent. In order to obtain the best and most efficient results, there must be complete understanding and harmony between the superintendent and the painting contractor. This is probably more important in tank work than in any other phase of the water-works business.

My past experience has brought me in contact with various types of contractors, one of whom I happened to catch applying two coats of paint on the same surface in one day, the second coat being applied during a thunderstorm. Needless to say, the contract expired right then. On the other hand, there are here in New England very responsible painting and maintenance contractors, who desire repeat business and who will co-operate 100 per cent.

Cost of Work

The old axiom that "you get what you pay for" is probably more true in water-tank maintenance than in most other projects. This fact is accentuated because the maintenance man is beyond your sphere of operations. Where he is swinging around in a boatswain's chair near the top of a 100-foot tank, you probably are not sitting beside him; he is working in a world of his own and you, under the circumstances, must have confidence in him. Because of the specialized nature of this occupation, it is quite logical that a premium be paid for this type of work and it will usually cost more to paint a tank than to paint a building several times its size. Bids for painting a ½-mil gal water tank can range all the way from $2,000.00 to $5,000.00 and it is often very difficult for the water-works superintendent to decide the issue. A "fly-by-night" contractor will take advantage of this situation and may submit a low bid, which is attractive at first thought, but in the long run will prove the most expensive.

Importance of Preliminary Inspection

On the assumption that you are dealing with reliable contractors, the cost of reconditioning a tank is pretty much in proportion to the amount of work to be done. This requires study on your part and necessarily an inspection of the tank, both inside and out. At this point a painting contractor who is in your confidence can be of real help.

Most of us realize that the preparation of a tank for painting is the most costly and painstaking part of the project. The coat of paint applied to a defective base is actually worse than nothing. It may look good for a few months, but will eventually have to be removed along with the defective base before the tank can be properly painted. It follows that the more material has to be removed, the more costly will be the work.

An inspection will usually reveal patches where the paint has failed, and the metal has become rusted and pitted, as well as the depth of the pitting. It will reveal blisters where the paint is still in place, but separated from the metal. In a riveted tank an inspection may reveal rivet heads on the inside rusted away, causing seepage. The inspection will reveal the types of coatings previously applied, principally on the inside. Many tanks have been painted with a hot tar or asphalt coating, which will require special treatment. Your inspection may reveal seepage through seams of a riveted tank. After you have seen all this, my advice is to sleep on it for about a week or, to be more realistic, think about it while lying awake nights; it will help you in keeping awake.

Extent of Work to Be Done

On completion of your week of deliberation the problem now arises as to what is to be done. It is a basic fact that there is no paint presently made which can be successfully applied to rust, scale, tubercles or blisters. It must be in contact with clean iron or with a previously applied coating, tight to the metal and in good condition. Theoretically this clean metal can be obtained by scraping, wire brushing, power sanding or sandblasting. I am opposed to scraping, as to me it seems a very tedious and uninteresting operation with, at best, only fair results. Power sanding and wire brushing can do a fairly good job if the conditions are not severe. Sandblasting undoubtedly provides the most satisfactory cleaning job, but as is usually the case with the best, is the most expensive. You have now reached the $64,000 question which is the heading of this paragraph, "Extent of work to be done".

There is no mathematical formula which can give you the answer; your good judgment is the formula for this situation. If the paint is hanging in ribbons, exposing a good deal, say one-half or more, of the metal, by all means go to sand blasting. If the annual budget will not allow this, don't do anything for a year or two and wait for finances to catch up with the situation. This is better than spending money on a poor job. If the old coating looks tight, say ¾ of it in good condition, a power brushing with possibly some scraping will prepare these smaller surfaces without too much labor—this is to be followed by a spot priming coat and complete coat of paint.

If your inspection reveals leakage in the seams or rivets, new rivets or caulking the metal is usually the answer. Seams in riveted tanks cannot be welded, because of expansion, resulting in leaks on either side of the weld. If you are confronted with an elevated tank having lattice work on one side of the legs, I do not know of any way to clean the inside of these legs other than by sandblasting. At this point serious consideration should be given to a long-term maintenance program. If the coating on the tank seems to be in a questionable condition, it is probably wise to sandblast down to clean metal and start the program off right. After the initial job, it is advisable to inspect the tank once each year or two and as soon as deterioration of the surface becomes evident, to apply a new coat of paint. A program of this nature results in a small expenditure frequently, but has the advantage of keeping the tank constantly protected and, in the long run, at no greater cost. After 25 years, depending upon frequency of painting, it will become necessary to sandblast again and start the process over.

You should by now have answered the $64,000 question and be in a position to prepare specifications for bids.

Paint

Due to the fact that following me on this program is a paint expert, I am very hesitant to say much on the subject of paint. It is immaterial as to who furnishes the paint, the painting contractor or the water department, but again you should consider the reliability of your contractor. It has been the policy of the American Water Works Co. to submit bids for

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paint separately, thereby providing their own material. I have followed this practice.

A few notes on paint have come to my attention which may be of interest for what they are worth. You cannot use ordinary lead-oil paints over a previously applied hot tar coating; the material to be used in this case is so-called "Apexia" or its equivalent, which is applied cold, the same as paint.

You cannot apply an ordinary lead-oil paint over graphite paint, as it will not stick. In applying more than one coat they should be of slightly different colors—to expedite complete coverage. Aluminum paint has proven to be most durable for outside coverage.

An Example

I wish to outline my experience with a standpipe which may be a typical case, but in some ways unusual. The tank was erected in Grafton, Mass., for the Grafton Water Co. during the year 1886 under the supervision of my wife's grandfather. It has remained connected with the family ever since, until the year 1953. This standpipe is riveted wrought-iron with a capacity of 100,000 gal, and is 25 ft in diameter by 30 ft tall, with a fixed iron ladder on the outside and a manhole. Even I can climb this one, although I have recently had trouble negotiating the manhole.

When I was given the job of managing this company in 1926, the tank was metal color and had not been painted since 1886; there was no paint on it either inside or out. In 1930 the idea was conceived, not by me, of applying a membrane, resembling burlap, to the interior and covering it with asphalt emulsion, which is a similar procedure to that used in waterproofing flat roofs. At the same time the outside was given a red lead coat, followed by aluminum. The membrane and emulsion lasted about three months, until ice and other non-co-operative conditions brought the membrane and emulsion all to the bottom. This was shoveled out the next spring without sandblasting. The tank was then painted with the usual red lead primers.

At the beginning of World War Two, leaks began to occur in the bottom ring of plates. Clean, round holes developed about the size of a pencil, with the resulting stream of water. I made wooden oak plugs and drove them in. This worked out very well until an accumulation of about 15 plugs began to make us wonder how long the tank would last. Because of the war no steel was available and there was considerable anxiety as to results in the town of Grafton, if this tank should suddenly give up. We drained the tank, permanently plugged the holes with iron bolts and applied several coats of the best paint.

About this time, around the middle of the war, the Electro Rustop Co. devised their apparatus to stop corrosion by the so-called cathodic protection method. We immediately purchased one and installed it on the tank. Up to about a year ago no more holes had developed. I have not checked with the superintendent since. My experience with cathodic protection is that it works, but I do not believe it replaces paint. In my estimation it can be compared to a watchdog, to protect any crack or failure which may develop in the paint coating.

The question of tank maintenance presents many intangible problems and one can argue moneywise as to the merit of not painting at all, as compared to a systematic maintenance and follow-up program.

Tank-Paint Manufacturers' Problems

by CHARLES J. GOTTHARDT
Vice-President, E. & F. King & Co., Inc., Norwood, Mass.

THE PROTECTIVE coatings manufacturer is confronted with several problems in the development of suitable paints for the maintenance of steel water-works tanks. He must produce a paint which (a) controls the mechanism of corrosion, (b) can be applied over various surface conditions, (c) will last a little longer than the owner expects, (d) is easy to apply, priced reasonably, and liked by the applicator, and (e) lastingly improves the appearance of the structure. Usually in problems there is a compromise permissible, but unfortunately for the tank-paint manufacturer, such is not true. Perhaps it is because of these problems that many paint manufacturers do not produce coatings for this purpose. It is a fact that most of these coatings are produced by manufacturers who specialize in corrosion-control paints.

Paint making is an ancient craft, predating history. First evidence of paint is found in the coloration of the scratch drawings of the men of the stone age on their cave walls. In each successive age of man, paint has made a contribution to progress, emerging today as a combination of decorative and protective media, dependent upon other crafts to produce surfaces which are to be decorated or protected, or both.

The underlying theme of the tank-paint manufacturer's problems is the control of the mechanism of corrosion. Now the mechanism of corrosion is not completely understood by science, but the electrochemical interpretation is generally accepted. According to the electrochemical theory, in the case of iron and steel, corrosion is the conversion of metallic iron into iron hydrates of the ferrous or ferric form through the presence of (a) water or moisture, (b) oxygen, and (c) an acid. The actual mechanism of rusting a primary reaction of iron and water, resulting in the liberation of hydrogen, which in turn is attacked by the oxygen and is thus removed from the surface, leaving hydrated iron oxide—otherwise known as rust.

Paints

With this understanding as fundamental, the knowledge of how certain basic paint chemicals can counteract this process must be utilized. It is fairly obvious that if the three agents of corrosion are denied access to the metal, there will be no corrosion. Hence, the coating must be continuous, so that the metal will be completely isolated mechanically. The coating must also be non-osmotic and non-permeable. But even the most perfect film cannot be expected to do the whole job, for the slightest rupture of the film or imperfection of application would neutralize the entire protective effect. Accordingly, a good second line of defense must be incorporated, which will control the corrosive agents through

means other than mechanical. This is accomplished by the introduction of certain basic pigments, which possess an oxidizing potential. In the corrosive process, as the iron substratum begins to corrode, ferrous ions are released, which combine with hydroxyl ions in the water, forming ferrous hydroxide. The basic pigments in the paint film cause oxidation of the ferrous hydroxide to ferric hydroxide, which is highly insoluble and is precipitated at the point of formation. Thus, the cathodic potential of the pigments results in the formation of an insoluble film over the anode or corroded area, causing the reaction to be stifled. This double-pronged approach is the basic tactic in the development of a protective coating for water tanks.

When we consider the pigments suitable for this class of service, the well-known rust-inhibiting stand-bys —red lead, blue lead and zinc chromate—must be eliminated for such reasons as solubility, possible toxicity or taste impartment. Remaining are lesser-known inhibitors, such as zinc dust-zinc oxide in combination, basic lead chromate and basic lead silico-chromate. All of these are very active and entirely suitable for tank paints, having none of the undesirable elements of the first-mentioned group.

The relative merit of the acceptable pigments is open to some argument. Based on testing in our laboratory, we rate them as equal rust inhibitors. In the case of basic lead silico-chromate, it is possible to increase the amount of active pigment in a given gallon by virtue of the fact that it is essentially a coating of lead chromate on a core of silica. Since the active portion of any pigment is the surface, it is possible to provide more active area per gallon by coating a light-weight core with a heavy pigment. As lead chromate weighs 56 lb per solid gallon and basic lead silico-chromate weighs but 34 lb per solid gallon, an appreciation of this advantage is evident. Basic lead silico-chromate is a relatively new development of the National Lead Co., having been on test for several years and now in pilot-plant production. The zinc dust-zinc oxide combination of pigments has been known for many years and is currently the only acceptable pigmentation for water-tank paint on government installations. Its single disadvantage lies in that the zinc dust must be combined with zinc oxide at the time of application.

The development of the continuous film for the mechanical aspect of the protective coating involves consideration of adhesion to steel and to other paint, elasticity under temperature changes, abrasion resistance, workability, insensitivity to immersion, and non-permeability. The paint industry and the Federal Government agree that the best all-round film to fit these considerations is produced by a phenolic vehicle. There are many vehicles which approach the 100% phenolic, but all of them are lacking one or more of the fundamental requirements. We feel there is no close second to the phenolic vehicle and, although we are alert to new developments, have seen nothing to date that we would care to consider seriously.

The combining of the pigment with the vehicle completes the basic tactic of tank-paint development, and all that remains to be done is to add the driers, adjust the viscosity, shade to standard color, check the uniformity and conformity to quality control, and to package. All of these steps are standard procedure and have no bearing on the problems in paints for the maintenance of steel water-works tanks.

Manufacturers of paints for water-works service have certain definite ideas how their products should be used. Technically, the responsibility of the manufacturer ceases when his product leaves his hands, because he has no further control over its application and use. His warranty to the customer is limited to the quality and composition of his product. Morally, the manufacturer is extremely interested in how his product is used for he is interested in seeing the fruit of his labor ripen into satisfied customers through satisfactory performance. Toward this end, the manufacturer first labels his product with a description of the contents and detailed directions for use. Literature is published, describing the products, uses, and method of application in greater detail, and it is here that the manufacturer makes his plea to do the job his way, in order that the product may serve you well.

System Paints

Tank paints are system paints in that they require more than a single coat. Usually a painting system provides a particular formulation for the contact with the steel, an identical formulation with a color modification for the intermediate coat and a slightly different formulation for the final coat. For systems involving two coat applications, the second coat ordinarily involves a color change only. On exterior surfaces, the primer is usually the same as applied to the interior, and the intermediate and finish coats are of a different formulation, particularly designed for atmospheric exposure and decorative in appearance. Systems of tank painting may differ, but all manufacturers agree that, whatever system you use, you should be consistent and stay with the same manufacturer's products for the entire job. This is most important, as compatibility of successive paint films is basic to satisfactory performance.

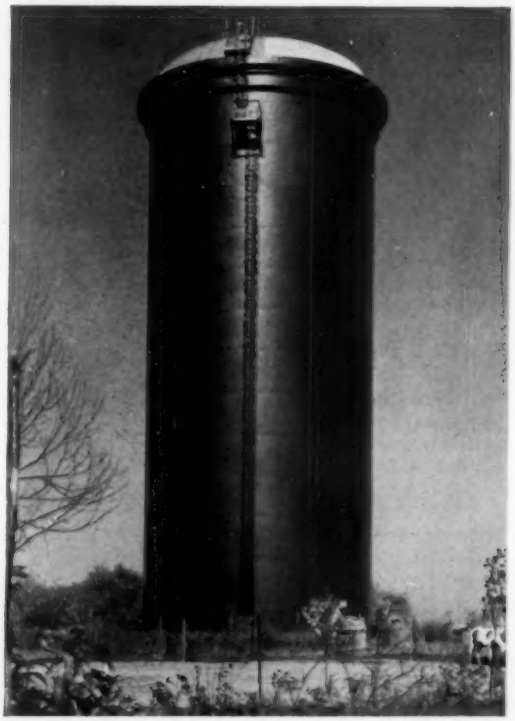
The preparation of the surface in tank-maintenance painting is a phase the paint manufacturer would like to stress, for optimum results rarely can be obtained unless careful and thorough work has preceded the actual spreading of paint. The most desirable surface for repainting is one that has been freshly sandblasted to bright metal. Second choice would be power sanding, wire brushing and scraping to remove all the rust, mill scale, and loose paint. We feel there is no third choice and, therefore, the preparation last mentioned is an absolute minimum. To do less is to invite premature paint failure and to defeat the whole maintenance program.

Paint films for steel water tanks total 0.002-in. to 0.003-in. in dry thickness, depending on the number of coats applied. On this paper-thin film rests the responsibility for the protection of a major capital investment. The paint manufacturer has poured his knowledge, experience and endless testing into his products, put it into a container and sealed the package. At this point, the manufacturer loses his control over his product, for, from here on, it passes into the hands of the applicator. The performance of the paint will be no better than the applicator's best effort and, conversely, the best application will be unsatisfactory with poor paint. When a tank-paint job fails, there is a quick juggling of responsibility by the manufacturer and the applicator, and to get at the truth is sometimes exceedingly difficult. Perhaps the paint is wrong, perhaps the application is poor, but more often the real cause of the failure may be traced to the tank owner, who prepared the specifications and let the contract. It is not always sound policy to award a contract to the lowest bidder, unless the specifications are precise and the owner will carefully supervise their adherence. Too often a contract is written and the job completed without the owner's taking the trouble to see that he is getting what he has ordered. Corners can be cut in preparation and application, and paint

BETHLEHEM

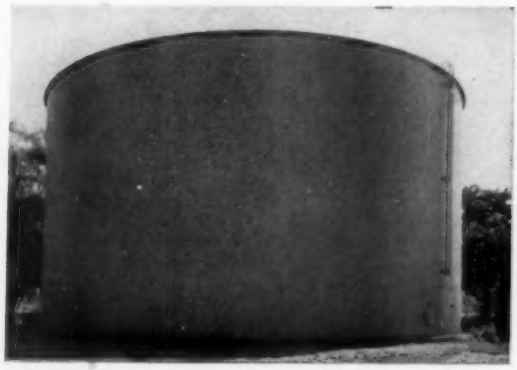
Water Storage Tanks

Welded steel tanks have many advantages for the storage of water above ground. They can be made permanently watertight; they are unaffected by climatic changes; they withstand damage due to shock, impact, explosion or surface settlement; they require little maintenance, and often cost less than competitive types of storage. The Bethlehem organization has nearly a century of experience in the design, fabrication and erection of tanks to A.W.W.A. and A.P.I. specifications. Here are a few which we constructed during the past few years.



AKRON, O.—This 1,500,000-gal standpipe, completed in 1955, is 115 ft high and 47 ft in diameter. It has an elliptical self-supporting roof and is dressed up with an attractive ornamental cornice.

WEST WARWICK, R. I.—Standing 52 ft high, this 1,000,000-gal welded steel reservoir was put into service in 1955. It is 58 ft in diameter and meets Specification D100-52 of the American Water Works Association.



ROCHESTER, N. Y.—This 1,500,000-gal welded steel reservoir was built for the New York Water Service Corporation, which engineered the job. It is 40 ft high by 80 ft in diameter.

BETHLEHEM STEEL COMPANY • GENERAL OFFICES • **BETHLEHEM, PA.**

BETHLEHEM STEEL

BETHLEHEM

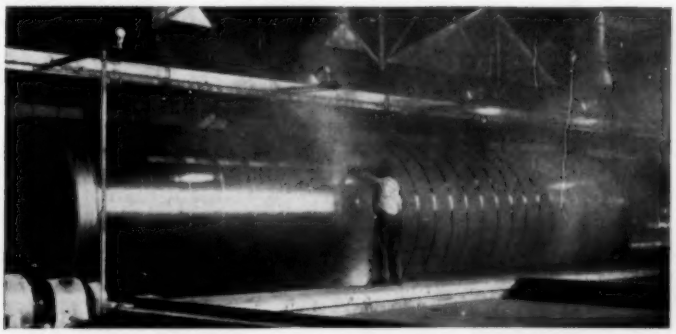
Tar-Enameled Steel Pipe

Sustained carrying capacity, bottle-tightness, resistance to damage, ease of installation and overall economy—these are the outstanding qualities of steel water and sewage pipe. And it is because these qualities add up to *better, more economical water service for the community* that, through the years, many of the nation's leading communities have installed Bethlehem Tar-Enameled Steel Pipe, not on a single project, but on job after job. Here are a few interesting projects completed during the past year or so.

QUEENS, N.Y.—Bethlehem Tar-Enameled Steel Pipe in diameters of 60, 48, and 36 in. was used to extend the Queens trunk main westward. The project required six miles of pipe.

READING, PA.—The newly-installed Northwest Pumping Main consists of 37,000 ft of 36-in. and 30-in. Bethlehem Tar-Enameled Steel Pipe. In the field the 40-ft pipe lengths were welded together to form 120-ft sections which were lowered into the trench, then joined with Dresser couplings.

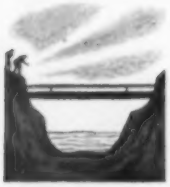
BOSTON, MASS.—The 60-in. pipe shown here was installed along the Charles River, virtually in the shadow of the Harvard University stadium, Soldiers' Field.



STEELTON, PA.—Newly enlarged facilities at Bethlehem's huge pipe shop permit the fabricating, grit-blasting, lining, coating and wrapping of pipe up to 96-in. ID.

• *For design data on Bethlehem Tar-Enameled Steel Pipe, please turn the page.*

6 Reasons why Steel Pipe is Best..



1 Beam Strength

Its tremendous beam strength, unmatched by any other material, saves steel pipe from damage in emergencies such as flash washouts. Multiple 40-ft lengths up to 120 ft may be handled without damage to the pipe. In fact, far longer sections have been regularly handled in the laying of thousands of miles of steel gas line pipe.

2 Corrosion-Resistance

Careful coating and lining with coal-tar enamel, in accordance with A.W.W.A. specifications, protects steel pipe from corrosion. The smoothly enameled pipe is impervious to corrosion and incrustation, and has flow coefficients as high as 150. We have modern shop facilities for coating and lining pipe up to 96-in. ID.

3 Shock-Resistance

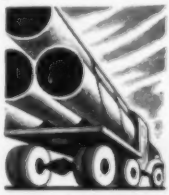
No other material can duplicate the shock resisting characteristics of steel pipe. Designed with a safety factor of 4 or more, Bethlehem Steel Pipe resists shock loadings, water hammer and surge; it can safely carry a load of nearly four times the working pressure. Steel pipe is always used for high-pressure penstocks and gas lines.

4 Leakproof Joints

Joints made with mechanical couplings, welds or by riveting, give unequalled protection against leakage from within and contamination of contents from without. These joints are strong, allowing the pipe to span washouts without failure at the joints. Dresser couplings are widely favored for their flexibility.

5 Resilience

The resilience of steel pipe makes it highly resistant to damage caused by vibration. It yields slightly under pounding of heavy traffic and shocks due to explosions, earthquakes and other external forces. Unlike rigid-walled pipe, steel pipe transmits loadings to the surrounding soil. Withstands heavy cover.



6 40 Ft Lengths

This means economy in laying the pipe. Only 132 joints per mile are required with 40-ft lengths of Bethlehem Steel Pipe, as compared to 300 or more joints required by shorter pipes. There is virtually no limit to the diameter; extremely large sizes can be shipped knocked-down for field assembly.

. . . and it's tested for strength!

Every length of steel pipe is hydrostatically tested after fabrication, ordinarily to 200 pct of the working pressure, in accordance with A.W.W.A. specifications.

This *tested and proven* strength of steel pipe is indicated by the chart below. The pressures shown are based upon the use of steel conforming to ASTM Specification A-283, Grade B, having a minimum tensile strength of 50,000 psi.

When exceptionally severe internal working pressures are encountered, the use of higher-strength steel is recommended. If you would like to have further information, kindly call or write the Bethlehem sales office most convenient to you.

THEORETICAL INTERNAL PRESSURES OF STEEL PIPE

	1/4 in.			5/16 in.			3/8 in.			7/16 in.			1/2 in.		
DIAM	WT LB/FT	MAX WRK PRESS PSI	MIN BURST PRESS PSI	WT LB/FT	MAX WRK PRESS PSI	MIN BURST PRESS PSI	WT LB/FT	MAX WRK PRESS PSI	MIN BURST PRESS PSI	WT LB/FT	MAX WRK PRESS PSI	MIN BURST PRESS PSI	WT LB/FT	MAX WRK PRESS PSI	MIN BURST PRESS PSI
18	49	445	1390	61	555	1735	73	665	2080	85	775	2430	96	890	2780
20	54	400	1250	68	500	1560	81	600	1875	94	700	2180	107	800	2500
22	63	365	1135	78	465	1420	93	550	1700	109	640	1985	124	730	2270
24	69	335	1040	86	420	1300	102	505	1560	119	585	1820	136	665	2080
30	86	270	835	108	340	1040	129	405	1250	150	475	1455	170	535	1670
36	106	225	695	130	280	870	155	340	1040	181	395	1210	206	445	1390
42	119	195	595	148	240	745	177	285	890	206	335	1040	234	380	1190
48	137	170	520	171	210	650	203	250	780	236	290	910	268	330	1040
54				192	190	580	230	225	695	267	260	810	303	295	925
60				214	170	525	255	200	625	296	235	730	336	265	835
72							309	170	520	359	195	605	408	220	695
84							357	145	450	412	170	520	470	190	595
96	The recommended minimum wall thickness is approximately the pipe diameter divided by 165. Pipe having this diameter-thickness ratio, when backfilled and properly tamped, will withstand any depth of cover. For buried pipe, the recommended minimum thicknesses are shown immediately above heavy black line.									470	145	455	539	165	520
108													*611	150	465
120													*669	135	415

Based on use of ASTM A-283, Grade B Steel, 50,000 psi min. ultimate tensile strength.
*Under certain conditions stiffeners may be required to reduce deflections.

$P = \frac{t \times Ts}{r}$ | P = internal pressure, psi | t = thickness, in. | Ts = allowable unit stress = 60% x 27,000 (yield point) = 16,000 psi | r = radius of pipe, in.

BETHLEHEM STEEL COMPANY

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BETHLEHEM STEEL

can be streched beyond its limit, without its being apparent at the onset. It is not meant that these practices are followed by all or even most applicators, for they know their reputation is at stake. However, the experienced applicators and lowest bidders are not always the same. To help the applicator and the owner insure a good job, as manufacturers we control the degree of hiding in our system paints. Thus, if a coat is over-thinned or stretched out too far, the preceding coat will show through. When spread at the recommended rate, total hiding is achieved.

How long a complete paint job should last on a steel tank in waterworks service is a question that must be answered in a "straddle the issue" manner. It is not unusual for a tank to go six years before repainting, but there are extremes on either side of this figure. The expected life of the paint depends on the basic soundness and quality of the paint, the quality of the preparation work, the workmanship of the applicator, the degree of job supervision by the owner, the extremes of temperature, and the chemicals introduced into the water. The most intelligent and, in the long run, the cheapest approach in tank-maintenance painting is not to wait until the film fails before painting, but to anticipate the job with a maintenance program, based on performance experience.

The problems of the paint manufacturer in producing protective coatings for steel water tanks are actually not solvable by him alone. The co-operation of the tank owner and the paint applicator is necessary if practical solutions to all of the problems are to be achieved. It is something of a question of integrity, respect, and confidence in each other. It is a sort of teamwork of a very high order, which works to the benefit of all.

The Painting Contractors' Problems

by ROY O. LEONARD

Contractor, Farmingham, Mass.

THE FIRST problem is that of "Price". As in every field, money is of paramount importance and I cannot impress upon you too strongly the old saying—"You only get what you pay for". You cannot get, or even expect to get, a thorough job, unless the price is commensurate with the work.

Usually, when a municipality owned tank is to be cleaned and painted, specifications are prepared and then invitations to bid are in order. It seems that in most cases the town or city awards the contract to the low bidder. This is unfortunate at times, because there are a few painting contractors who cut the bottom out of the price just to obtain the work. Then—unless an inspector is on the job with them eight hours a day—they are apt to omit a coat of paint or otherwise do a poor job, in order to get out of the contract alive. This is really a problem, as it not only deprives the honest contractor of work, but it hurts the owner, because it will only have to be painted again that much sooner, and makes him disgusted with tank painters in general.

I am not saying that every job we do is 100 per cent, because in painting, as in every field, the human equation enters and things sometimes do not turn out as they should. However, upon being notified, we always try to return and correct the error.

We always advocate that if a town or water district hasn't sufficient funds in the budget to do the entire job the right way, it is better to do the part that needs the most attention thoroughly and leave the balance until the necessary funds are available.

Interior Rigging

Another problem we are coming into contact with more and more is that of rigging the interior of some of these newly designed tanks. On some there are hooks welded to the under hide of the roof which are of absolutely no value. Some tanks are built with holes in the roof, into which a threaded plug is inserted. Very often these holes are placed in the wrong part of the tank and are of no assistance to the tank painter. It has almost come to a point where the average steeplejack has to be an acrobat in order to paint some of the hard-to-get-at areas. The Factory Mutual Insurance Co. in Boston insists that tanks on property on which they hold fire insurance be painted and kept in first class condition. I have discussed this matter with their Mr. Sweet several times, and they are quite concerned over the absence of any rigging fixtures. I believe that Mr. Sweet has contacted tank builders, to try to have some provision inserted in the specifications to take care of this situation.

Then, there is the problem of seepage around the rivet heads and seams. This occurs in older-type tanks and it is virtually impossible to make such a tank 100 per cent water-tight by the chipping and caulking method. We have discussed this matter with various engineering firms and tank manufacturers, but up to this time, the problem is not solved. We have tried blasting all the interior seams and rivet heads to virgin metal, and then brushing on several coats of one of the so-called liquid metals, but even this has not proven 100 per cent satisfactory. We believe that only by welding every seam and rivet head can the tank be made 100 per cent water-tight. Unfortunately to most municipalities the cost of this method is prohibitive.

Weather Problem

When painting tanks, the weather is often a major problem. All tank painters know that no paint should be applied when the temperature is below 40°, or in damp and rainy weather. Another effect of the weather encountered while painting a standpipe or elevated tank that is full or partially filled with water, in humid weather, is that of condensation. It is a good practice, if possible, to have the tank emptied. This will eliminate the possibility of the moist warm air's condensing on the cold plates of the tank. This condition is not as apt to occur on a tank used for sprinkler systems only, because the level and temperature of the water remain constant. However, in the case of a standpipe used on a water-supply system, where cold water is pumped in and out several times a day, the water has no opportunity to establish a temperature balance with the exterior atmosphere. We have had our troubles with condensation and try to avoid them by making sure either that the

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all types...all sizes

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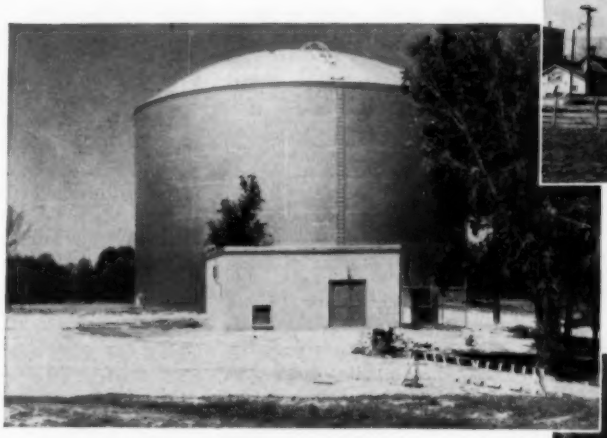
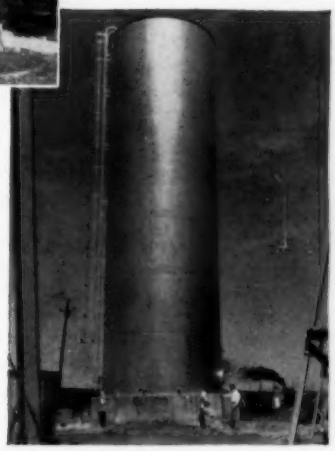
ELEVATED WATER TANK
75,000 gallon capacity. This type of tank is available in standard sizes and elevations.



GROUND LEVEL TANK
One of four 2,500,000 gallon water storage tanks fabricated and erected for The City of Kirkwood, Mo., and The St. Louis County Water Co.



STANDPIPE
This 125,000 gallon standpipe is a typical example of the large variety of standard sizes offered by Nooter.

with EVERY NOOTER TANK *you benefit from:*

- **Deliveries You Can Depend On.** Work scheduling is an important aspect of Nooter fabrication . . . *dependable* delivery dates are a basic policy with Nooter.
- **Competitive Prices.** Solid prices backed up by sound money-saving techniques, resulting from 59 years of tank-fabrication.
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humidity is very low or that the tank is empty when we paint.

There is another difficulty that we have encountered with many paints on the market today—and that is that they cannot be applied in the late afternoon and still retain their gloss, even though there is no apparent moisture in the air. While this is not a major problem, it does cost the painting contractor a considerable amount of money in the course of a year—repainting these areas.

Before painting a tank, the first problem is in deciding upon the cleaning method to be used for that particular tank. Unless the metal is properly cleaned, it is a waste of money to apply any paint. I shall outline briefly the various methods that we use, in cleaning the surfaces to be painted.

In cases where it is found that the paint film has not broken down, but only blistered and rusted in spots, these spots should be thoroughly cleaned with wire brushes, scrapers or chipping hammers, whichever are necessary. A power wire brush is very effective in many instances. After this type of cleaning, interior areas usually receive two complete coats of paint. Exterior areas are patch-coated and then receive one or two complete coats, as deemed necessary.

Sandblasting

However, where the steel is badly pitted and rusted, we believe that sandblasting is the best cleaning method. Sandblasting a surface consists of directing a controlled, fast-moving mixture of sand and air all over the surface to be cleaned. The fast moving particles strike with such force as to remove all scale, rust, paint and other foreign material, leaving the surface bright and clean.

The sand mixture comes to the operator through a specially constructed ¾-in. hose from a container that holds 800 lb of sand under a pressure of 125 lb per sq in. At the operator's end of the hose, there is a hardened steel or ceramic nozzle, that cuts the ¾-in. flow down to a ¼-in., causing it to leave the nozzle at a high velocity and with great cutting power. The average consumption of sand a day is about three tons. It is very important that the area which is sandblasted each day be primed immediately upon completion of blasting.

With regard to new tanks, the plates are usually delivered all descaled and primed, with the exception of a 2″ strip around all edges of the plates. This allows an unpainted surface for the welder to work on when joining the various plates together. Upon completion of erection, the welded seams and the 2″ margin around them, together with all abraded spots, must be thoroughly cleaned of rust and slag, and primed with the same make of primer as was used on the balance of the sheet. The tank is then ready for the painter to apply the successive intermediate and finish coats. The kind of paint to use for a given surface used to be quite a problem, but, thanks to great advances in chemical research made by the paint manufacturers, better inhibitive and adhering primers and more pliable paint film, with greater water-excluding qualities, are now available. This means longer life for the paint and greater protection for the surfaces and—in the final analysis—reduced upkeep.

I should like to mention some of the factors involved in the painting of new water tanks. First of all, we must consider the sheets of steel. As they come rolling off the rolling mills, each sheet usually is covered with a thin layer of tightly adhering iron oxides—commonly known as mill scale. It is impossible to roll and fabricate these sheets without cracking this scale. And once it is broken, galvanic action in the presence of moisture starts between the bare metal and the mill scale and spreads rapidly beneath the rest of the scale. Obviously then, to obtain a reliable surface for painting, this scale must be removed. The four methods by which this can be accomplished are as follows:

Sandblasting
Pickling
Flame cleaning
Weathering

Since we have already spoken of sandblasting, I shall proceed with the pickling, which by the way, is the method most frequently used on steel plates for water tanks. After fabrication, the sheets are dipped in an acid solution and remain submerged for the length of time necessary to remove all mill scale. After this process, they are rinsed, dried and given a shop coat of primer.

Flame cleaning consists of passing over the surface of the plate with a series of oxyacetylene burners, arranged in the form of a rake. As these burners pass over the surface, the mill scale actually snaps off, due to the differential expansion. In other words, when the intense heat is applied to the mill scale, it expands rapidly and breaks free from the main sheet, which remains comparatively cool. The ideal time to prime is as soon as possible after the removal of scale, while the surface is still warm. This excludes moisture and allows the paint to gain closer contact with the metal.

Weathering as a means of removing mill scale is just as the name implies. After erection the tanks are allowed to remain exposed to the atmosphere for a period of about twelve months. This allows the mill scale to loosen and fall off. Any that is left will usually come off quite easily with a wire brushing. Then the whole surface is given a complete wire brushing and primed.

Benefits of Effective Metering

In critical water supply problems, metering is essential to conservation

by MORRISON B. CUNNINGHAM
Supt. & Engr., Water Dept., Oklahoma City, Okla.

EFFICIENT USE of water meters is generally conceded to be one of the most effective means of operating a well-run water supply system. Certainly metering is an essential element in furthering the conservation of this vital commodity—particularly important in an era of increased demand and widespread shortages.

The design, metals, workmanship, operation and maintenance of water meters have been of special interest to me, not only in my own city, but many places in the United States. As president and vice-president of the American Water Works Association for the past three years, I have met with water works men in many sections of the United States and discussed our mutual problems, including those relating to water metering.

The proposal to grant tariff concessions on foreign-made water meters is a matter of great consequence to the water works industry. In my opinion, such concessions would be a threat to the most efficient and practical means available to water works and the nation to reduce water consumption and to thereby control the increasingly critical national water supply problem.

I will attempt to show the basis for this opinion by outlining (1) the relationship of meterage to supply; (2) the double threat to adequate parts supply inherent in tariff concessions, to wit, (a) the dangerous dependency upon foreign parts which would result, and (b) the likelihood that our domestic source of parts will be destroyed by foreign prices; (3) the likelihood that present essential services in constructing meters suited to local waters and in advising on the proper adjustment and maintenance thereof would soon be eliminated, or at least greatly reduced, by domestic meter manufacturers and, since not required under competitive bidding, would not be provided by low-price foreign meter suppliers. Their service is not the heart of the bidding, but it is a service that they include in their price schedule on the competitive bidding.

The fourth point is the inability of municipalities under local laws to protect themselves from these detrimental effects of low foreign bids which, in the long run, threatens the continuance of effective water metering in this country.

Metering Efficiently Reduces Consumption

It is universally recognized by water works officials that metering is the most efficient method of reducing consumption and encouraging water conservation. Each customer pays for what he uses on this basis. This practice ends needless squandering of water and encourages the fixing of the leaks which waste water. It is generally recognized that with the use of a water meter, 50 per cent of water consumption is saved.

Without the use of water meters, the actual needs of a community would be doubled. Therefore, it would be next to impossible to finance the construction of water supply systems—and not only these systems but other enormous investments such as filtration plants, pumping stations and distribution systems which would become necessary without adequate metering. The distribution system represents, on the average, about 75 per cent of the total investment of the water system.

I might say at this point that to find additional water supplies has become increasingly expensive and, in some locations very difficult. It is a real problem and an expensive one, especially in areas where water supply is of great importance.

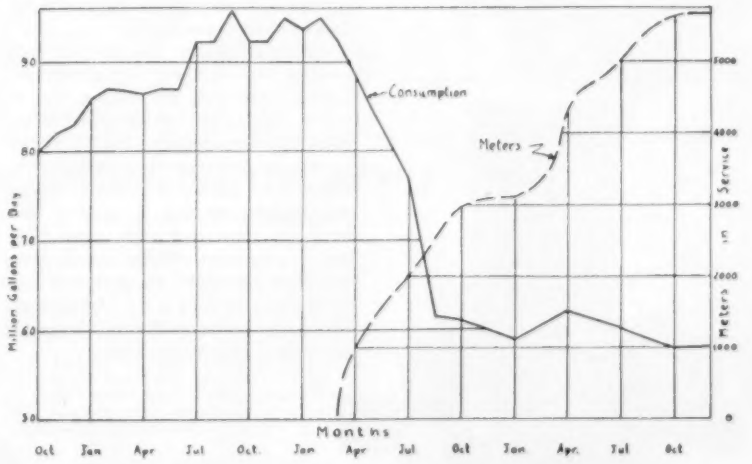
To show the importance of water meterage, I should like to review the present water supply situation and the increased demand for water. Increased consumption of water and the expanding requirements of industry have made the conservation of the nation's water supply a problem of national importance.

In our opinion the use of water meters is the best way and about the only way we can enforce water conservation.

The value of the meter industry of the United States, in peacetime as well as in time of war, is playing an important role by providing skilled workmen and plant facilities for the construction of water meters: water meters properly designed with proper metal alloys to meet the variable qualities of water, and workmanship which in addition furnishes a ready supply of inter-changeable repair parts available to the water departments.

Savings from Accurate Metering

I started to work for the Oklahoma City Water Department in 1920. My



EXHIBIT—This graph of the relationship between metering and water consumption (Water & Sewage Works, May 1954) was among exhibits submitted to the Commission.

NEPTUNE METER COMPANY

MAIN OFFICE: 19 West 50th Street, New York 20, N. Y. • FACTORY: 22-42 Jackson Ave., Long Island City 1, N. Y.

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TRIDENT WATER METERS

. . . Job Tested Ten Million Times

For over 50 years, more Trident meters have been purchased than any other make. Most of these . . . even the oldest . . . are still running accurately. This long serviceable life means lower amortization, obsolescence and replacement costs.

Trident meters have long led the field in design improvements, and today are the finest, most modern meters available. Every improvement has been made to fit all older Tridents. This is one of Trident's biggest advantages.

A planned schedule of testing and repair with Trident meters gives you a continuous program of meter modernization . . . at far less cost than scrap-and-replace methods. Repairs take less time, too, aided by Trident's extreme simplicity. A moderate stock of only the *latest* parts services *all* your Tridents. You waste no time searching or waiting for parts for old meters. Trident parts are *always* available. Your repair men have no obsolete models to learn. If they can repair one Trident, they can repair all . . . efficiently, economically.

TRIDENT METERS FOR DOMESTIC SERVICES IN COLD OR WARM CLIMATES

Trident meters combine fine-instrument construction with the inherent high accuracy achieved only in disc-type, positive displacement water meters. Accurate at all rates of flow within normal test flow limits and remarkably sensitive to small flows.

Trident Frost-Proof Meter embodies the original frost-proof meter feature. If the water freezes and expands, the cast iron bottom cap breaks, relieving the working parts from strain. The bottom cap can be replaced at very nominal cost. For warm climates, the Trident Split-Case Meter is recommended.

Among exclusive features for long accurate life are: Gear train is fully oil-enclosed, including the stuffing box, to isolate vital parts from abrasives, turbulence, corrosive elements, and to provide permanent lubrication. Anti-friction thrust roller absorbs disc thrust, making the Trident virtually immune to disc breakage. Heat-proof, hard rubber bushings in gear train and register are interchangeable. Sand ring keeps abrasive material out of working parts. Materials are corrosion-resistant, with special materials for unusual corrosion problems.

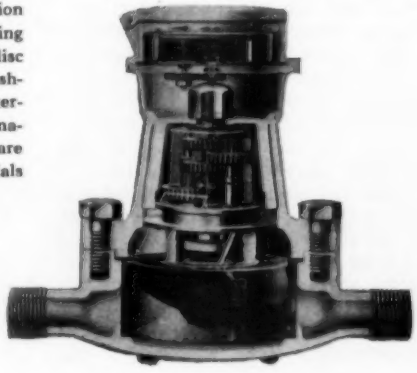
Easy to service and repair . . . makes big savings in meter costs over the years. Register has no screws. Chamber is snap-joint. Disc is in three parts, easy to adjust. Guide pins, slots, etc., assist in assembling meter properly.

Trident Frost-Proof Meters

Size In's	Wt. Lbs.	Lgth. In's	Wdth. In's	Ht. In's	Base to Center of Pipe	*Del. U.S. Gal. Min.
5/8	10 3/4	7 1/2	5 1/2	9	1 3/4	20
5/8 x 3/4	11 1/2	7 1/2	5 1/2	9	1 3/4	20
3/4	15	9	6	9	1 3/4	30
1	26	10 3/4	9 5/8	9 3/4	2	50
1 x 1 1/4	26	10 3/4	9 5/8	9 3/4	2	50

Trident Split-Case Meters

Size In's	Wt. Lbs.	Lgth. In's	Wdth. In's	Ht. In's	Base to Center of Pipe	*Del. U.S. Gal. Min.
5/8	9	7 1/2	5	8	1	20
5/8 x 3/4	9 1/2	7 1/2	5	8	1	20
3/4	12	9	5 5/8	8 5/8	1 1/16	30
1	20	10 3/4	7 1/2	9	1 5/8	50
1 x 1 1/4	20	10 3/4	7 1/2	9	1 5/8	50

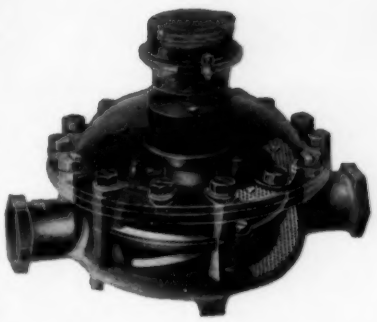


NEPTUNE METER COMPANY

STYLE 3 TRIDENTS FOR MEDIUM RATES OF FLOW

A disc-piston meter for commercial and other installations requiring medium rates of flow larger than household consumption, but not great volumes. Also excellent for "battery" settings where preferred for metering wide flow ranges. In addition to sensitivity on low flows inherent in disc meters, it has the Trident oil-enclosed gear train, heat-proof removable bushings in register and gear train, interchangeable parts and other Trident features which give it sustained accuracy and low maintenance cost. On 1½" and 2" sizes, a "delivery adjustment" can be regulated in relation to line pressure to prevent racing.

These two sizes of Style 3 Meters do the work of any compound meter of equivalent size and, being simpler, they do it with less cost for maintenance and repair.



Trident Style 3 Meters

Size In's	Wt. Lbs.	Lgth. In's	Wdth. In's	Ht. In's	Base to Center of Pipe	*Del. U.S. Gal. Min.
1½ Scr.	36	12⅝	10	10⅝	2⅜	100
1½ Flge.	40	13	10	10⅝	2⅜	100
2 Scr.	58	15¼	12 7/16	11¾	3⅛	160
2 Flge.	61	17	12 7/16	11¾	3⅛	160
3 Flge.	105	24	16 7/16	17⅛	3⅛	300
4 Flge.	257	29¼	22 1/16	20⅝	4⅝	500
6 Flge.	589	36¾	29	25⅝	5⅞	1000

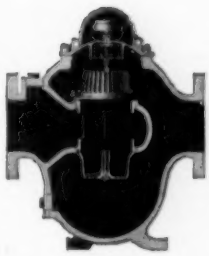
CREST METERS FOR BULK WATER DELIVERIES

For "bulk" water deliveries at periodic or continuous high rates of flow—i.e., where mains deliver water to adjacent townships; hydraulic elevators, cranes, pile-jetting apparatus, etc., the Crest Meter is recommended. Of the velocity type, a turbine is rotated by the water at a speed directly proportional to rate of flow. Among features is the hollow hard-rubber turbine revolving on agate bearing, resulting in minimum friction, maximum sensitivity, sustained accuracy. Standard Trident register and gear train features. All parts interchangeable.

Trident Crest Meters

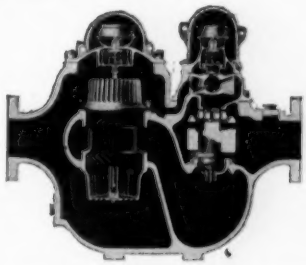
Size In's	Wt. Lbs.	Lgth. In's	Wdth. In's	Ht. In's	Base to Center of Pipe	*Del. U.S. Gal. Min.
1½ Scr.	65	12¾	8½	16¼	6⅜	100
1½ Flge.	65	13	8½	16¼	6⅜	100
2 Scr.	83	15½	8⅞	16¾	6⅞	170
2 Flge.	85	17	8⅞	16¾	6⅞	170
3 Flge.	250	24	13⅝	27¼	13¼	400
4 Flge.	260	24	13⅝	27¼	13¼	700
6 Flge.	300	24	14⅝	28¾	14¾	1600
8 Flge.	500	26¾	17½	30¼	15¾	2800
10 Flge.	800	30	26⅝	29¼	13⅞	4400
12 Flge.	1200	36	30½	34⅞	16½	6400
16 Flge.	1950	42	36½	40⅞	19¾	12400

Am. Wt. Wks. Asso. & New Eng. Wt. Wks. Asso. Std. Specifications



COMPOUND METERS FOR WIDE WORKING RANGES

Use this Compound Meter for services with a maximum demand beyond the range of equivalent disc meters—yet with the probability of occasional small rates of flow. Accurate over a wide working range. Measures high rates of flow through a Trident Crest Meter unit and small flows, which cannot be recorded accurately by the Crest, through a Trident Disc Meter unit. In addition to the standard Trident features of both these meters, a specially constructed valve automatically directs the water to the proper unit, depending on rate of flow. Single cast iron casing. All parts interchangeable.



Trident Compound Meters

Size In's	Wt. Lbs.	Lgth. In's	Wdth. In's	Ht. In's	Base to Center of Pipe	*Del. U.S. Gal. Min.
3	460	33	13¾	27⅛	13¼	320
4	475	33	13¾	27⅛	13¼	500
6	685	36½	14⅝	28⅝	14¾	1000
8	970	42	17½	29⅞	15¾	1600
10	1500	45 7/16	20⅝	29⅛	13⅞	2300

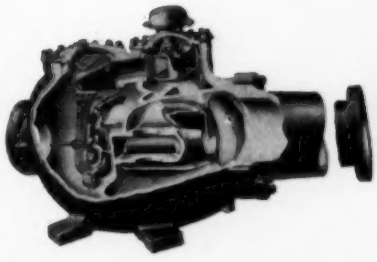
PROTECTUS METERS FOR FIRE SERVICE LINES

Designed for fire line use where both high and low flows occur, and loss of head is an important factor. Meets such requirements with (a) accuracy on all flows and (b) low loss of head plus reliability of operation, satisfying both Water Works officials and Underwriters. Measures low flows through a Trident Disc Meter unit. Large flows are measured proportionally by a Trident Crest unit. Water-way is clear, unobstructed. Both units have standard Trident features which insure accuracy, long life and low maintenance cost.

Trident Protectus Meters

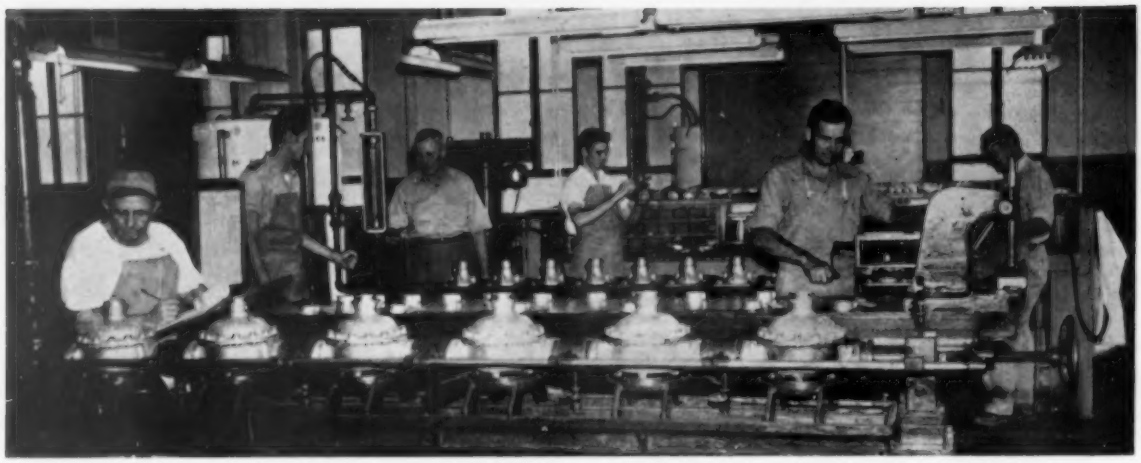
Size In's	Wt. Lbs.	Lgth. In's Incl. Incr.	Wdth. In's	Ht. In's	Base to Center of Pipe	*Del. U.S. Gal. Min.
3	700	64⅜	22¾	21½	8	400
4	900	67	24	24⅝	8	700
6	1600	83⅛	29	27½	10	1600
8	2250	89¾	32¾	30⅞	11¾	2800
10	3400	98⅛	38½	37⅝	14⅜	4375

Am. Wt. Wks. Asso. & New Eng. Wt. Wks. Asso. Std. Specifications



NEPTUNE METER COMPANY
New York 20, N. Y.

See Page R-176 for Branch Offices and Factories



METER TESTING—A meter testing shop at Van Nuys, Calif., illustrates equipment employed in this necessary routine practice.

first assignment was to investigate the factors causing the sale of only 46 per cent of the water that was pumped into the distribution system. One of the contributing factors was found to be that the city had not availed itself of the services offered by the meter industry with respect to advice concerning water meter maintenance and the availability of repair parts.

Consequently, a large number of the meters were out of service and in many instances the customer was paying an estimated, or flat rate, bill. The cooperation and services of the water meter industry, the training of meter repair mechanics, consultations on making repairs and the availability of interchangeable repair parts, made it possible for us to recondition some 12,500 meters in 1920 and 1921. The result was an increase in the sale of water to 80 per cent of the water pumped. That represented a considerable saving.

The use of water by city departments was metered even though they did not pay for water. We found the city's use to average about 10 per cent, and we have since maintained the water meters in the system to where the unaccounted-for water amounts to only three to five per cent of the water pumped.

We have maintained close consultation with the meter industry and their representatives to the extent that by observation of design, metal alloys and workmanship, the quality and dependability of water meters have increased their efficiency about four times over the 1920 figures. For example, in 1920 we required four meter mechanics and four servicemen in the field, each with a car, to maintain 12,500 meters. Today, we have 79,600 water meters, with three meter mechanics and three field servicemen.

I think that is an example of the close cooperation of the water works people working with the manufacturers in using a standard specification, a general specification, and then going into special detailed requirements of metals to fit a particular water need. That was certainly true in our case.

Quality Meters and Good Service

I would like to give you a few examples of what I mean by the quality that goes into a water meter which is needed to give good service, free of unnecessary and expensive field maintenance and shop repairs.

The material, metals and parts of the design which applies to the water of Oklahoma City does not necessarily apply to a town 25 miles away, because each water supply has its own individual water characteristics. A town that has a water of even temperature (like well water or a supply outside the low-temperature zones) can get a close tolerance, but a town where there is a wide range of temperature, from above freezing to 80 to 90 degrees, must have more clearance. If there is inadequate clearance between the disc and the disc chamber, expansion will occur, the meter will stop, and the customer will get a prorated bill.

The meter manufacturers, through their field offices and local representatives, have over the past 50 years built up valuable service organizations, which are made available to the water departments of communities in the United States, without charge. The meter industry has available the services of metallurgists who are experienced in the behavior of metals in water.

Meter Manufacturers Are Specialists

Even the larger water departments would have difficulty in independently financing this type of consultation. When we stop to think that there are 16,000 water departments in the United States, serving more than 100,000,000 people with water, and that eighty per cent of these departments serve communities of 2,500 or less, we can see how it would be natural for the water works people to depend to a very large extent upon the valuable experience of the water meter industry representatives.

We depend on them to keep advised of the local water conditions in order to supply water meters of the best quality design, metal alloy and workmanship, to meet the local demand for a meter having a long useful life, relatively free of expensive field and shop maintenance.

It has been my observation that it takes years of experience and judgment for anyone to observe and determine metals that give good service and those that do not give good service.

I cannot conceive of a foreign-made meter company furnishing a meter to the water works industry of the United States which could meet these existing demands. Nor can I conceive of a foreign meter exporter having the incentive or the particular experience with American waters to duplicate these existing special services and know-how of the American meter industry, at least within the foreseeable future.

Domestic meter manufacturers provide and participate in extensive advisory and educational services relating to meter maintenance and adjustment. Field representatives of the meter manufacturers of the United

States have participated in Water Works Short Course Schools which are conducted annually in most of the states, and District Meetings and Special Schools, such as those for the study of water meters, are conducted one or more times annually in many of the states. Representatives of the meter manufacturers always take an active part in this work.

Potential Danger in Foreign Supply

To sum up, let me state that, as a practical matter, the price advantage which a tariff concession would give to foreign meter companies would assure their obtaining water works business on a very large scale within a relatively short period of time. These foreign meters, so purchased, would in time of war or whenever the foreign manufacturer decides to go out of business or abandon their American market, become unusable or "dead" meters.

In addition, the destruction of or substantial injury to the domestic meter industry resulting from foreign competition would drastically impair and ultimately eliminate parts replacement for the thirty million odd American meters—that represents at least an investment of $400 million, and the replacement would be calculated at least double that amount or more—now in use as well as the other services in proper construction and maintenance of meters which are presently available only because American meter companies can presently afford to provide local water works and are, in my opinion, essential to truly effective metering.

I have no doubt that a market torn between indifferent foreign exports and a dying domestic industry can, in the short run as well as in the long run, produce only great hazards to our water works industry and to effective water conservation.

Renovating Water Meters

WATER COMPANIES, on the whole, and also several of the more progressive municipally owned Water Departments, have found that a little dressing up of overhauled meters before returning them to the customers' service has a desirable psychological effect on the customer. The spray gun and gilt or silver lacquer or a combination of the two is the most universally employed method of dresing up old meters after they have been overhauled and tagged "O.K." on the test bench.

La Verne Trentlage, of the Water Department of Elgin, Ill., has evolved a scheme which goes the spray-gilting method one better in making "new" meters out of old ones. In the Elgin scheme the metal parts of the meter are given a treatment which removes the oxidized or carbonated coating from the metal and leaves the parts as metal-bright as when turned out by the manufacturer.

Cleaning and Brightening Procedure

(1) Dip meter parts for 10 minutes in *hot* Trisodium Phosphate solution (2½ lbs. or more of T.S.P. in 10 gallons of water).

(2) Remove meter parts from T.S.P. solution and rinse in *hot* water to remove the alkali.

(3) Dip the parts in Muriatic Acid solution (1 part 18 degree Muriatic Acid—to 2 parts of water). Allow to remain in this acid bath for approximately 15 minutes, or longer if necessary. Remove and rinse in hot water.

(4) To brighten to original lustre, immerse in the "bright-dip" solution (1 part 38 degree Nitric Acid, 1 part 66 degree Sulphuric Acid and I part water, plus a handful of common salt). Leave the parts in the bright dip for 5 to 10 seconds, the length of time depending on the composition of the metal and degree of brightness desired.

(5) Remove and rinse in *boiling* water to remove acid.

(6) To keep the parts from dulling on standing, a "stabilizing-dip" (especially prepared for this purpase) has been developed by General Chemical Company). After the rinse, the parts are dipped into this solution, removed and allowed to drain and dry.

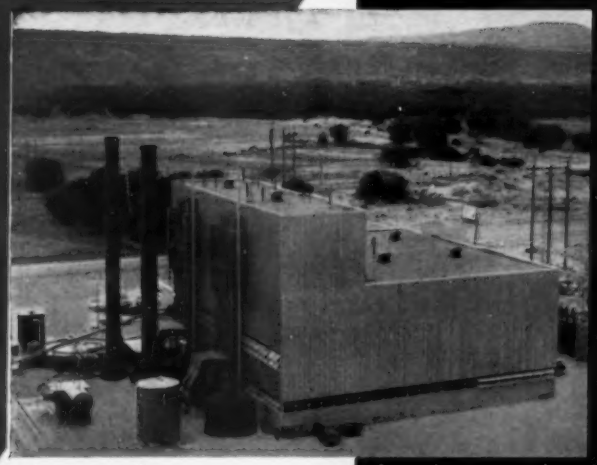
Notes of Caution: Always add acids to water and *not* water to acids when making dilutions. This will preclude over-heating and spattering of the acid. Be careful to avoid splashing of the acid when dipping the meter parts. In case acid accidentally splashes on hands or face, wash at once in clean water to avoid an acid burn. Spattered acid is also hard on clothing and shoes. Rubber aprons and gloves are good protection.

Do not use iron or steel wire for dipping meter parts. Copper or monel metal wire is satisfactory.

★

four different water supplies from one water treatment plant by GENERAL FILTER

The Plains Electric Generation and Transmission Co-operative recently completed at Algodones, New Mexico, provides 30,000 kilowatts per hour to Southwest consumers.



Consulting Engineers:
Laramore & Douglass, Inc., Chicago, Ill.

A water treatment plant capable of providing suitable water in sufficient quantities for four different supplies was required by the consulting engineers:

- COOLING WATER for the condensation of turbine steam.
- SANITARY WATER for drinking and sanitation.
- MAKE-UP WATER for the boilers.
- SERVICE WATER for fire protection and general utility.

With the system installed one operator can check, alter and control the treatment process from a master control panel . . . confident of complete dependability . . . minimum maintenance.

AERATORS • FILTERS • TASTE AND ODOR • ALKALINITY CONTROL • HIGH CAPACITY RESINOUS ZEOLITE • IRON RUST REMOVAL • DEMINERALIZATION • SOFTENERS

Ask for recommendations for a water treatment plant "job-engineered" to your requirements . . . a fast, efficient, economical system by General Filter.

General Filter Company
AMES, IOWA

". . . better water"

WATER TREATMENT

THE TREATMENT of water for domestic or industrial use is commonly termed water purification. This is a relative term; it refers to the removal of undesirable matter (suspended and dissolved) and bacteria in order to make the water acceptable for use.

The kind of treatment employed in water purification depends on the use for which the water is being prepared and the character and amount of the matter to be removed. For domestic use, that is, for human consumption, removal of bacteria is of primary importance, but removal of turbidity, color, tastes and odor is also desirable from the standpoint of the consumer. Industrial processes, too, often require more elaborate purification than water for domestic uses.

The steps in water purification include several unit processes: Coagulation, sedimentation, filtration, disinfection, aeration, adsorption, chemical oxidation, ion-exchange, chemical precipitation and stabilization. Aeration, adsorption and chemical precipitation are used in softening and iron and manganese removal. Stabilization is a method of corrosion control. These steps not only involve unit processes but also special equipment.

Coagulation and Sedimentation

Coagulation is accomplished by the addition of chemicals to water. This involves the use of chemical handling equipment, chemical feeders and chemical feeder controls, mixing and flocculation equipment, and tanks in which the necessary reactions can proceed.

Sedimentation provides for the removal of suspended or precipitated matter by allowing these particles to settle under the influence of gravity. Sedimentation is accomplished in tanks which are designed to produce the desired detention time and are equipped with valves, level controls, and devices for removing the settled sludge. Some of these latter devices are mechanical and provide for continuous removal of the sludge.

The subject of coagulation and sedimentation and chemical handling are discussed under Section IV of this Reference & Data Edition.

Filtration

When water is passed through beds of porous material, suspended matter is removed. The common material used in water plants is relatively fine sand although crushed anthracite is also used. This sand is contained in some structure with a valve system for controlling the flow of water and an underdrain collection system. There are two types of filters; slow sand filters through which water is passed at rates of 0.016 to 0.16 gal per sq ft per min and rapid sand filters through which water is passed at rates of 1.6 to 3.2 gal per sq ft per min, sometimes at higher rates.

The actual removal of suspended and colloidal matter by filters is accomplished in several ways. Particles larger than the voids between the sand grains are strained out and form a mat, termed a Schmutzdecke, which in turn strains out smaller particles. Precipitation of colloids by adsorption on the relatively large surface of the sand grains also removes matter. There is also a flocculation which takes place in the filter and these flocs build up on the surface of the sand grains thus increasing the area of the surface which can adsorb matter.

Microorganisms also aid in the filtration process. They form sticky coatings on the sand particles which attract and hold other particles. These organisms may also act on these substances and actually cause a chemical change to take place. This is particularly true in slow sand filters.

Most treatment plants in the United States use rapid sand filters (sometimes called mechanical filters from the early designed which used mechanical rakes in cleaning). Filter plants are usually constructed with several units which operate in parallel. Usually, the number of units is some multiple of two and the size of the filters is such that each can treat an appreciable percentage of the maximum daily load on the plant. The capacity of the filter may be from 25,000 to 10 million gallons per day. In designing the filter plant, it is generally planned to have a reasonable number of units of reasonable size.

The filter consists of an underdrain system commonly termed a filter bottom, of which there are several kinds (Wheeler bottom, porous plate, perforated tile, brass strainer, etc.). Above the filter bottom there is usually a shallow layer of coarse gravel on top of which is a layer of 24 to 30 in. of fine sand, the size of which is important. In place of silica sand, crushed and graded particles of anthracite coal is also used.

Valves are used on the inlet to the top of the filter, and on an outlet to the sewer, also above the filter and connected to troughs above the sand to carry off wash water. An outlet valve and rate controlling valve are used on the effluent line from the underdrain system of the filter. Another valve is placed on the effluent line to waste and another on a wash water line which is connected to the underdrain system for forcing water upward through the sand for washing.

An instrument to determine the loss of head through the filter indicates the extent to which the filter has become clogged by accumulations of dirt. This is known as a loss of head gage. A gage is also connected with the rate of flow controller to show the rate at which water passes through the filter and to totalize the amount filtered. Each filter is usually equipped with an operating table which controls the opening and closing of the various valves.

When the filter becomes clogged with impurities removed from the water, the loss of head increases and eventually reaches a point where the filter will not pass water at the desired rate. It is then time to wash the filter. This is done by shutting off incoming water, closing the effluent valve, opening the surface waste outlet, and opening the wash water valve to admit water to the underside of the filter.

The object of filter washing is to remove the filter sand, all the matter accumulated thereon during filtration. Passage of water upwards through the sand or anthracite coal ("Anthrafilt") at rates of 15 to 30 inches of rise per minute is enough to lift the sand particles and cause them to scour against one another. The rate at which wash water is applied, as measured by the rate of rise of water level, is controlled to prevent sand being washed out of the filter, but should be high enough to cause the sand bed to expand by 50 percent.

The length of the washing period will vary for different conditions but generally three to five minutes is sufficient. To improve the scouring action on the sand grains during washing high pressure water jets are used at the sand surface. The Palmer filter wash uses rotating jets. Air may also be injected at the bottom of the filters. Uniform distribution of wash water throughout the area of the filter is essential to good washing. At the end of the washing period, the valving system is adjusted to accomplish filtering again, but the first water through the filter is wasted. Water from the filter goes to clear water storage usually after chlorination.

Disinfection

Not all of the bacteria in water are removed by filtration and some water supplies are not turbid enough to require filtration but do contain some bacteria. In both cases (and with well waters too), a chemical agent is added to destroy these bacteria or assure that none will grow. This process is intended to kill off harmful bacteria and not necessarily to kill every single organism. Therefore, it is termed disinfection rather than sterilization.

The most common agent used for disinfection is chlorine or a hypochlorite compound which will release chlorine. This subject of chlorination is discussed in Section V of this Reference & Data Edition and will not be discussed at this point.

Other agents used for disinfection include chlorine dioxide, bromine, ozone, ultra violet light and silver compounds. Chlorine dioxide has been used more for taste and odor control than for disinfection; bromine is used for swimming pool water disinfection; ultraviolet light has been used in industrial process waters and silver compounds only for small quantities of water.

Aeration

The purpose of aeration is to improve the quality of water, usually by removing unwanted tastes and odors or carbon dioxide. Aeration is accomplished by bringing the water into intimate contact with air. This contact may be brought about by aerators of several types. Air diffuser aerators introduce air from blowers through some porous media in fine bubbles at the bottom of a tank and the air passes upward through the water sweeping out the undesirable tastes and odors.

Waterfall aerators consist simply of a pipe for discharging the water at some height and allowing it to fall through the air; cascade plates, slotted plates, shelves, steps, etc. aid in breaking up the water as it falls. Spray nozzles probably create the greatest breakup of water particles and hence the largest surface exposed to air, but it requires considerable head to produce the spray. Many water plants operate aerators only when taste and odor problems exist, principally in the summer time when algae growths abound.

Taste and Odor Removal

Tastes and odors in water supplies come from natural or man made causes; natural sources include algae, leaves, decaying vegetation, etc. man made tastes and odors come from sewage and industrial wastes. Algae are generally the worst offenders.

The only practical method for measuring odors is the "Threshold Odor Test." Odor is evaluated by an operator smelling samples of the odorous waters that are diluted with various amounts of odor-free distilled water. The odors are vaporized by controlled heating in order to make it easier for the operator to make his observations.

The Threshold Odor Number is obtained by dividing the volume of odor-free dilution water by the volume of odorous water, when a dilution is reached above which the odor cannot be detected. Definite threshold numbers can not be set for all supplies but a hot threshold number of more than two can often be noticed by consumers.

Two methods are used for the control of tastes and odors due to algae. The first is to control the growth of algae in the water supply. This is termed preventive treatment. Copper sulfate added to the reservoirs in controlled amounts will kill off algae before the numbers of organisms reach proportions that will cause severe tastes and odors. Preventive treatment within the water plant includes good housekeeping, particularly by keeping coagulation and settling basins and filters clean.

Corrective treatment includes aeration, chemical oxidation, and adsorption. Aeration has already been discussed. Chemical oxidation includes treatment with chlorine dioxide, ozone, and chlorine; adsorption utilizes activated carbon.

Chemical Precipitation

Chemical precipitation is involved in coagulation to produce the floc desired, but it is employed to a greater extent in water softening by the lime-soda process. This subject of water softening including the ion-exchange process is presented in some detail in Section V as are iron and manganese removal.

Stabilization

Waters which contain carbon dioxide or have a pH below neutral for other reasons tend to be corrosive to mains and household services and hot water tanks. Waters which have a high pH due to softening tend to deposit carbonates in mains and services or to be corrosive to hot water tanks. Treatment to overcome both of these tendencies is stabilization; treatment to prevent corrosive action is commonly termed pH adjustment or corrosion control and the word stabilization is more generally applied to treatment of softened waters which are super-saturated with calcium carbonate, or which are low in alkalinity due to excess lime treatment.

Stabilization of lime softened waters may be accomplished by recarbonation with carbon dioxide gas, by the addition of alum which is both acidic and flocculates the carbonates, or by the addition of sodium hexametaphosphates, of which Calgon is an example. Treatment with the glassy phosphate is known as "threshold treatment" because a very small amount of phosphate will inhibit excessive precipitation of the carbonate.

Fluoridation

The addition of fluoride compounds, termed fluoridation, is not a treatment method in water purification. Rather it is a process of adding a chemical to the water supply as a carrier in order to provide a micronutrient to the diet of the consumers. It has been shown that the presence of approximately 1 ppm of fluoride ion in water will decrease the incidence of tooth decay in children and in adults who drink such waters regularly as a child. The addition of fluorides to water is a public health measure, and water works personnel and plants usually act only as the agent in carrying out the will of the people where it is decided that fluoridation should be practiced.

Laboratory Control

All water purification practices should be carried on subject to laboratory control. This subject of laboratory control has been discussed in Section IV.

Design and Operating Problems in Small Plants

by THOMAS R. LATHROP
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TO a great extent, the problems of the small and large treatment plant are similar. The raw waters of both produce the same problems of purification, including chemical application, filtration and disinfection. The differences in operation are the result of differences in plant design and also in the type of personnel usually employed.

A plant with a capacity of 0.5 mgd. or less is considered a small plant. the plant operator usually is responsible for the entire system, from operating low-service pumps to reading the meters and sending out bills. This discussion, then, will be confined to plants 0.5 mgd. or less. Even in this category, many plants are provided with the same features as larger ones, and treat waters presenting similar problems of turbidity, tastes, odors, hardness and bacterial contamination. Some small plants also have well-trained operators. But differences in design, operating conditions and personnel problems do occur.

All water treatment plants constructed in Ohio must have the approval of the Ohio Dept. of Health. A few regulations governing these plants are: (1) The rate of filtration required is 2 gpm. per square foot in purification plants using surface waters. In the case of softening and iron removal plants, using ground waters, a 3 gpm. rate is permitted. (2) Filter rate controllers are required on all filters. (3) Open gravity filters are required for all surface waters, but pressure filters are permitted in softening plants which treat ground waters. (4) Settling basins having at least four hours' detention are required at all plants using surface waters, although for ground waters which are softened shorter detention periods are allowed.

Design Features

The construction of completely new water works including treatment plants so taxed some of the small municipalities that the water works structure was not made large enough to provide space for chemical storage. The filters reach almost to the roof, making it very difficult to get into a filter and even more difficult to remove and replace the sand and gravel. At some plants of this sort a small building adjacent to the filter building is used for storing chemicals. Such arrangements add to the problems of operation.

Reaction and Settling Units

Cylindrical steel reaction and settling tanks, which are often employed for economy's sake, usually afford rather inefficient mixing. In some plants where the lack of effective mixing has been noted, the addition of mechanical mixing devices has improved conditions. When lime-soda softening is involved, the steel tank serves as a mixing chamber, settling basin and recarbonation basin, with recarbonation occurring in the outtake pipe. The water is generally not stable when it reaches the filter, and the sand encrusts rapidly.

Filter Washing

Surface washing not only keeps sand in filters in clean condition, but in the softening plant it reduces the rate of incrustation of the sand. In the small plant, surface washing can be provided from piping which is usually on hand. A small grid of 1-in. pipe placed in such a filter makes an excellent surface washer. It is simple to construct and is so small that it can be easily handled if it becomes necessary to remove it from the filter.

Chemical Feeding

Chemical application for the small plant is usually provided by solution feeding devices. A few of the dry feeders will apply chemicals accurately in the small amounts usually required. Too often the chemical storage space is in the same room as the filters and pipe gallery, where moisture conditions affect the chemicals—especially lime and soda-ash—so that they cannot be fed accurately by any volumetric dry feeder. Incidentally, accuracy of chemical application is more important in the small plant than in the large one. Over- and undertreated waters are much more apt to reach consumers in small communities.

Recarbonation

The recarbonation of lime-softened water presents many problems in all plants, and the small plant is no exception. When natural gas is available, a gas burner is usually employed for producing carbon dioxide. Kerosene burners are generally more satisfactory in the small plant than coke burning furnaces, because operation is usually intermittent and a small coke fire is difficult to keep burning. Recarbonation units employing dry ice (solid CO_2) are of great advantage, although the cost is perhaps somewhat more than for carbon dioxide generated as a product of combustion. There is no problem of generation or compression; the dry ice is delivered in sizable blocks which are cracked up and placed in a screw capped pressure cylinder. The gas coming from the top of the cylinder is measured by a rotameter and diffused through a submerged fabric hose of the type used for watering lawns or gardens and sold under the name "Soil Soaker." Excellent results are reported.

In some small lime softening plants, recarbonation is not practiced because of the difficulties involved. Vitreous phosphate known as "Calgon"* is applied in an effort to offset the effects of water saturated or super-saturated with calcium carbonate. This treatment prevents the incrustation of the filter sand pipelines, meters, etc.—but, if water is treated with excess lime, the vitreous phosphate does not remove the causticity and a caustic taste often remains.

Filters

Pressure filters are installed as an economy measure at certain small water treatment plants. In Ohio, the installation of pressure filters is discouraged and such units are permitted only at plants designed for ground water softening or iron removal. Very little need be said about the disadvantages of this type of equipment. Tastes and odors at times develop in these units as a result of biological growths. The sand cements together, and overhauling such filters is a disagreeable job.

Gravity filters are occasionally constructed using steel shells, some as small as 5 or 6 ft. in diameter. Concrete units providing 25 sq. ft. of filter area are about the smallest size that should be constructed. Smaller units are too difficult to work in during construction and overhauling operations.

*This paper originally presented before the Annual Meeting of the Am. Water Works Assn., and published by the permission of the Association, is condensed here.

*Produced by Calgon, Inc., of Pittsburgh, Pa.

Rate Control

Rate controllers are most economically constructed for one or two filters by employing a float chamber which provides a constant head over an orifice. The only problem of operation is to keep the float valve working freely. Putting a proper cover over these controllers is quite important if foreign matter is to be kept from the clear well. The type of rate controller usually supplied employs a hydraulic valve actuated by pressure on a diaphragm and is very satisfactory in the plain filtration plant. It is of little use in many lime-soda softening plants because the pilot becomes encrusted and the controller fails to function. If vitreous phosphate is introduced into the water ahead of the filters, this trouble is eliminated. However, a water harder by 20 ppm. may be expected when this chemical is applied to the water before filtration.

Pumps

Pumps in the softening plant using pressure filters usually take suction from the settling tank discharging through the filter into the distributing system. In softening plants this arrangement has the serious drawback of causing incrustation of the pump runner and housing, making it necessary to take the pump out of service about once or twice a month for removing calcium carbonate. This coating is very hard and crystalline in character. An acid bath is the most effective method of cleaning. To remedy the condition, the high-service pumps may be arranged to take suction from the filter effluent instead of the effluent. When the water passes through the filter before it reaches the pump, it has become more stabilized and little further trouble is experienced with incrustation. Vitreous phosphate applied to the suction of the pump will also prevent incrustation of the pump by calcium carbonate.

Filter Washing

A wash water tank is usually lacking in the small plant. Sometimes a a pump is provided, but very often the wash water is drawn from the main discharge of the plant to the distribution system. This is practical if there is an elevated tank on the system and if the filters require only a relatively small amount of wash water. At one plant, with a 6-in. force main about two miles long, the single filter was divided into two parts of washing purposes, so that enough wash water would be available from the small force main with its high friction loss. It is desirable that an auxiliary gate valve regulating the rate of filter wash be placed on the main wash water line so that wash water valves on each filter can be opened wide without danger of upsetting the sand and gravel bed.

Automatic Controls

Clear wells have been omitted in some small plants in order to reduce the cost. Pumps take suction directly from the gravity filter effluent line and dishcarge into the distribution system. An elevated tank usually floats on the system, but somtimes a pump with automatic controls discharges into a hydropneumatic tank. The pump is in frequent operation during certain parts of the day. At some plants, the pumps will start as often as once a minute, operating for from 10 to 15 seconds at a time. Treating water under these conditions certainly presents problems which the large plant operator never encounters. Automatic equipment, actuating low-service pumps, chemical feeders, filters and the like, materially facilitates operation of a plant of this type.

Operating Problems

Raw waters from impounding reservoirs often contain algae. For the most part, the small plant operator does not determine what organisms are involved but employs copper sulfate in varying amounts at different locations. Usually the copper sulfate is applied on more or less of a schedule, such as once or twice a month. If the conditions are not improved, a supervising chemist may be called upon to advise a treatment.

The aeration of well waters is frequently accomplished adjacent to the filter building. Spray from the aerator saturates a brick building wall and the chemicals stored inside near the wall will take up so much moisture that it becomes impossible to feed them with a dry feeder. Separation of the aerator from the building is advisable.

Mixing devices at some softening plants require a great deal of maintenance because the small plants operate intermittently. Sludge collects on the bottom of the basin during the period of shutdown and makes it difficult to start the mechanism, with breakage often resulting.

The operation of filters in the plain filtration plant is largely a matter of keeping the filter material clean and free from mudballs. In the lime softening plant, the problem of maintaining filters is much more serious. The sand becomes heavily incrusted and at times cements together, forming large chucks and slabs. The operator must be continually on the watch to prevent this condition. The filters should be prodded with a long-handled rake each time they are washed, so that the operator may know the condition of the sand. As previously stated, a surface wash system will prove very helpful in preventing sand agglomeration. Frequent removal of sand from the surface of the filter is necessary to keep the sand level at a point below the bottom of the wash troughs. When sand is heavily incrusted, little or no sand expansion takes place during the washing operation. The effective size of the surface sand often reaches 2 mm. or more. Below the surface the size is much smaller.

In washing purification plant filters, the operator must learn to work the wash water valve slowly. Valves in small plants are usually manually controlled and often cannot be opened too rapidly, but many are opened fast enough to upset the gravel layer. The carborundum-plate filter bottom which is coming into use should prevent troubles resulting from displaced gravel layers.

Tastes and odors are attacked in the small plant in about the same manner as in the large one. The operator of a small plant does not have the facilities for making threshold odor tests. And he may not have the training to test for *free residual* chlorine. Activated carbon and combined chlorine are usually employed for taste and odor control. *Free residual* chlorination is used for taste removal at a few small plants where the operator is competent to control it.

Disinfection at the small plant is usually best accomplished with hypochlorite rather than with liquid clorite is, overall, more economical clorite is, overall, more economical as well as being more simple in operation.

The maintenance of the plant in a neat condition is more of a small than a large plant problem, as the small plant often has no space for storage and becomes cluttered up with all sorts of equipment. In building small water works plants provision must be made for chemical storage, tool and meter room, and general storage space if anything approaching neatness is to be attained by the operator.

A small amount of effort toward landscaping the works will greatly improve its appearance. The planting of trees and shrubs can be done with no outlay of money because individual citizens or the garden club can be depended on for material if the water works man indicates an interest.

Notes On Water Filtration

by GEORGE E. SYMONS, Ph. D
Consultant & Technical Editor, Larchmont, N. Y.

FILTRATION is a process of removing suspended matter from a liquid by passing it through a porous medium. In water treatment plants this medium is a granular material such as sand, anthracite coal or diatomiaceous earth.

Types of Filters

There are four types of filters: Slow sand, rapid sand, pressure, and filter-aid filters. In the first two the filter medium is contained in a structure open to the atmosphere. The pressure filter is a closed pressure tank containing the filter medium. The filter-aid filter is a special pressure filtering device as will be described later.

In both types of sand filters, the bottom of the structure contains an underdrain or collecting system. Above this underdrain system, there are successive layers of stone, coarse gravel, fine gravel and sand. The lower layers are but a few inches deep but the sand layer is from 12 to 30 inches deep depending on the designers preference. In the slow sand filter the underdrain system acts solely to collect the water which filters downward, under the force of gravity, and lead it to storage. In rapid sand filters, the underdrain system not only collects the filtered water but serves as a distribution system for forcing water upward through the sand filters to wash the filter. (see discussion of backwashing, later) In slow sand filters the top layer of sand is scraped off at intervals until it is necessary to clear and refill the sand bed.

There is another fundamental difference between slow sand and rapid sand filters. In the former the rate of flow of water through the filter is usually 4 to 6 mil gal per acre per day. In rapid sand filters the rate of flow through the filter is from 125 to 250 mil gal per acre per day or 2 to 4 gal per sq ft per min. Older practice used the lower rate but modern practice where the water is prepared better, higher rates are used.

Media

Sand, or quartz granules free of lime and magnesium carbonates, is the most common material used in filters. The size of the sand grains is frequently stated as "effective size" in millimeters. Effective size is that size sieve opening through which 10 per cent will pass and 90 per cent be retained. Effective sizes usually are 0.35 to 0.50 mm. Inasmuch as this effective size could be 90 per cent large grains and 10 per cent small, a 'uniformity coefficient" is introduced into sand specifications. It is the ratio of the diameter of a sand grain just too large to pass a sieve that allows 60 per cent of all the sand to pass, to the diameter of the grain size that is just too large to pass through a sieve which will pass only 10 per cent of all the sand. The uniformity coefficient should be 2.0 or less.

A less confusing method of specifying filter sand size was proposed by Thos. Riddick, Consulting Engineer of New York. This specification is shown in the accompanying table.

Filter Sand Specification (After Riddick)

Sieve Series Tyler	Number U.S. Series Equivalent	Opening mm	Retained on Sieve Min Percent	Retained on Sieve Max Percent
65	70	0.208	0	1
48	50	0.295	0	9
35	40	0.417	40	60
28	30	0.589	40	60
20	20	0.833	0	9
14	16	1.168	0	1

Within the past two decades, other media has been suggested for rapid sand filters, in particular, granular anthracite coal. Diatomaceous earth is used in the filter-aid filters, but since this is an entirely different type of filter, it will be discussed later.

Principle of Filtration

The purifying action of a sand filter is both physical and colloidal in character. Obviously, the particles removed are smaller than the openings or passage ways between the sand grains. These particles, turbidity, bacteria, and floc are caught and held in two ways. Sand grains gather a negative charge as slightly alkaline water passes and positive colloidal particles of floc are attracted to the surface of the sand grain. Secondly, small particles and bacteria adhere to sand particles and others are held back as logs caught in a log jam. Most of the filtering action takes place in the top few inches of a rapid flow sand filter.

In the slow sand filters these particles tend to be removed at the surface of the sand. A thin layer of gelatinous organic matter, bacteria and floc collects on the surface of the sand and this layer, termed a "schmutzdecke" acts as a fine pored filtering mat and is the principle factor in filtration in the slow sand filter.

Operating Factors

Loss of Head: The total depth of filtering media in a rapid sand filter is about four feet and the water level above the sand is usually maintained at 4 to six feet above the sand surface. Thus the difference between the water level in the filter is from 8 to 9 feet. In other words the available head to force water downward through the filter is 8 to 9 feet.

Frictional resistance to the movement of water through the filter causes a loss of head. These frictional factors include size of sand grain, depth of sand and gravel, type of underdrain system, and clogging due to dirt and floc particles on the surface of the sand and between the sand grains.

Filters are usually designed so that the loss of head in a clean filter is not more than 1 to 2 ft. Several types of filter bottoms have been designed to minimize the loss of head due to that factor.

The longer a filter operates, the more dirty it becomes, with a consequent increase in loss of head. When the loss of head reaches 8 to 10 feet, a filter has reached its effective capacity and should be washed. Guide to the need for washing is the loss of head gauge. If the loss of head exceeds the total head available, a partial vacuum (i.e. negative head) exists in the filter and air binding will result.

Rates of Operation: Rapid sand filters are designed to filter water

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Anthrafilt and Its Application

Anthrafilt is made from a **selected** Pennsylvania anthracite which has been cleaned so as to have a minimum ash. This cleaned anthracite is then screened and classified hydraulically to yield sizes suitable for filter purposes.

Anthrafilt is used as a mechanical aggregate in place of sand and gravel in all kinds of filters, i.e.

Rapid gravity filters	Slow filters
Swimming pool filters	Pressure filters
Hot process softening filters	Oil removal filters
Cold process softening filters	Alkali filters
Mechanical sewage filters	Acid filters
Revolving screen filters	Sewage sludge-beds
Portable filters	Household filters

The entire filter bed may be made up of Anthrafilt of various sizes or only the top layer may be of Anthrafilt over the usual bed of gravel.

Advantages of Anthrafilt

High Filtration Rate: Rates up to 200 mgad are obtainable with Anthrafilt without sacrifice of effluent quality. The accepted average rate with sand is 125 mgad.

Long Filter Runs: The larger, irregular Anthrafilt grains allow less clogging with algae or other fibrous substances. The angular grain surfaces provide greater entrapping areas for the removal of turbidity and bacteria. The differences in shape and specific gravity of the grains, by decreasing classification after back washing, allow the whole depth of the filter bed to be active in the filter operation.

Low Wash Water Costs: The long filter runs and consequent less frequent washing and the low degree of packing after back washing combine to cut the usual wash water requirements at least in half.

No Cementing with Lime, Manganese or Iron: Lime will coat on Anthrafilt but this coating readily flakes off without any cementing action if filters are properly operated. Manganese and iron salts precipitated on Anthrafilt by the lime treatment are easily removed by back washing.

High Degree of Expansion: 50% expansion is obtained with half the back wash velocity required for sand.

Coarse Sizes Can Be Used: The irregular shape and natural filtration characteristics permit the use of much larger sizes with equal results.

Gravel Beds Stay Flat: No ridging or mounding and less cracking and pulling away from side walls during operation.

Low First Cost: Lighter weight per unit volume balances the cost differential between Anthracite and sand and saves on freight and handling charges.

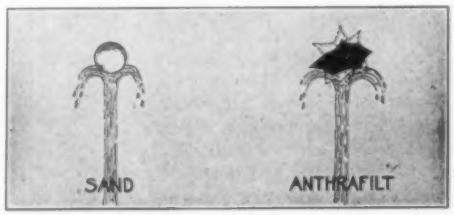
Filtration Characteristics

Anthracite granules are irregular shaped and of varying densities. Weights run about 53 pounds per cubic foot as against 100 pounds for sand. The irregular shapes provide greater porosity resulting in more rapid filtration with no loss in character of effluent and with considerably less loss of head.

The variable densities of Anthrafilt particles cause less classification after back washing and the lighter, irregular shapes allow easier expansion and more effective cleaning.

The greater bulk of Anthrafilt requires less tonnage per filter bed. Attrition losses amount to less than 0.25% per year.

Anthrafilt successfully removes lime, iron and manganese salts and will not form a permanent coating under proper conditions of treatment and filter operation. Lime flakes off easily without cementing and the iron and manganese salts are readily removed by back washing. Oil is easily removed from boiler water after coagulation with ferric sulphate, ferrous sulphate or alum. Anthrafilt can also be used for the filtration of acetic and sulphuric acids and caustic soda solutions. Being insoluble in alkaline waters, Anthrafilt produces silica-free water in hot process water softening.



Upward impulses of water produces greater agitation of angular grains, hence Anthrafilt beds are cleaned more effectively.

Anthrafilt No. 1 is usually made in sizes ranging from effective size of .60 m.m. to .80 m.m. the uniformity coefficient is less than 1.75 in all sizes. We can make smaller sizes or larger sizes, but for special cases only. The remaining sizes of Anthrafilt are as follows:

No. 2. Anthrafilt—3/32"x3/16"
No. 3. Anthrafilt—3/16"x5/16"
No. 4. Anthrafilt—5/16"x9/16"
No. 5. Anthrafilt—9/16"x13/16"
No. 6. Anthrafilt—13/16"x1-5/8"
No. 7. Anthrafilt—1-5/8"x2-7/16"
The above sizes have 20% tolerance.

ANTHRAFILT ECONOMY

When Used in Existing Filtration Plants

Increased capacity with same plant
Decreased volume of wash water
Lower maintenance cost through elimination of ridging, mounding and air binding.

When Used in New Filtration Plants

Lower plant investment
Lower cost per cubic yard
Lower wash water costs
Lower maintenance costs

at 2 to 4 gal per sq ft per min. Modern practice leans toward the higher rate, but whatever the rate, it is the practice to maintain the filtration rate constant throughout the filter run, i.e., between washings. Since a gradual increase in loss of head means a decrease accordingly of rate of flow, through a filter, a mechanical rate controller is used to keep the flow at the original preset rate. This rate control is accomplished by opening the effluent valve proportionately as the loss of head increases. Rate controllers consist essentially of a Venturi tube which measures the flow of water and operates a diaphragm actuator to regulate the valve opening.

Washing: When the loss of head gage indicates that a filter has become dirty or clogged with impurities removed from the water then the filter must be washed. This is done by shutting off the influent and effluent valves and opening a waste water valve to the filter troughs above the sand.

Washing consists of passing water upward through the sand at a rate fast enough to expand the sand bed and flush out the impurities. In practice, wash water is admitted to the filter underdrains under pressure, at first slowly until the sand bed is expanded and then more rapidly. The rate of filter wash water must be at least sufficient to cause the water level to rise 15 inches per minute; modern practice provides for a wash water rise of 24 to 36 inches per minute. This rate requires an upward flow of 15 to 22.5 gal per min per sq ft of surface.

The upward flow of water "floats" the sand until it occupies about one third more volume (i.e. a 50 per cent expansion); it also causes the sand grains to rub against each other and scour off impurities adhering to the grains. The upward flow of water also carries with it the mud, floc particles, bacteria and other impurities, which are discharged through troughs in the filter to the sewer. When the wash water appears fairly clear, the filter is considered clean.

To prepare a filter for return to service the operator reverses the steps of operation. First the wash water is reduced in rate to allow classification of the sand, then shut off altogether. The waste water valve is closed and the filter influent valve is opened, and the filter effluent run to waste for a few minutes before it is discharged to the clear well. This practice assures a better filtered water since the bacterial removal of a filter just washed may not be very good.

Modern equipment now takes the filter washing work out of the hands of the operator. With an automatic control system he needs only to be warned that the loss of head has reached the maximum desirable limit, and he pushes a button and the back wash cycle is automatically instituted. A back wash timer provides two or more back wash rates—an initial low rate to break the sand surface, expel air and provide maximum scrubbing action between sand grains, followed by a high rate for fully expanding the bed to flush out the dirt and then a low rate to allow the sand to classify as it settles back. Wash rates can be varied as to intensity and duration from a central control panel and manual variation is possible for individual filters in a group. It is possible to make the filter washing cycle completely automatic initiated by loss of head in the filters.

Modern filter design practice includes a surface wash system, by which jets, under a head of 50 to 150 ft, discharge water at the sand surface. These surface wash jets may be stationary or on rotating arms. In operation, the surface wash is started just prior to opening the back wash valve; this action breaks up the mud cake on the sand surface; the sand bed starts to expand almost immediately by the normal upflow wash. The surface wash is continued until the water overflows the troughs, and then may be shut off or it may be continued until just before the wash water is cut off.

Older filter designs of rapid sand filters included an air wash system. This is a grid of pipes between the underdrain system to force air through the bed and agitate the sand before the upflow wash begins. This system is seldom installed today.

Filter washing, when performed properly, cleans the sand completely and prevents the accumulation of mud balls, and subsequent shrinkage and cracking of the sand bed. Thus efficient filter operation is assured and tastes and odors due to growths in the filter are prevented.

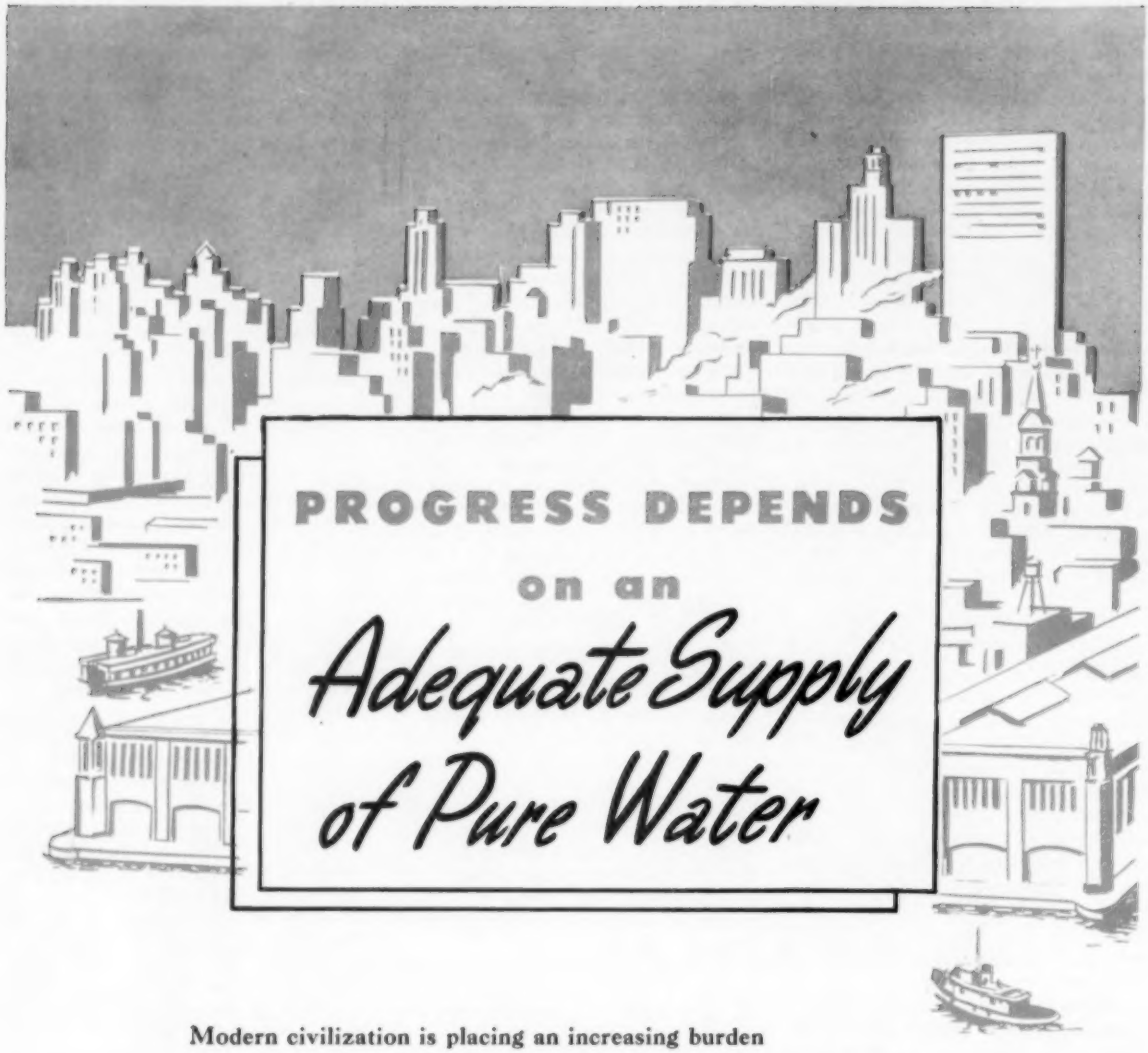
Slow sand filters use a smaller size sand grain and a slow rate of filtration. When the loss of head reaches the maximum allowable limit, the filter must be cleaned. Cleaning is accomplished by draining the bed and shovelling off the top layer of dirty sand. The sand may be removed by wheelbarrow, ejector or conveyor. This dirty sand is cleaned by special sand washers which use a jet of water and violent agitation. The surface of the sand is stripped every time the loss of head requires it until there is no more than 2 ft of sand left in the filter bed. Then 6 to 12 inches of clean sand are added to bring the sand bed to its original depth.

Filter-Aid Filter: This filter consists of a layer of finely divided particles deposited upon a porous supporting membrane which serves as an underdrain. The size of the particle is such that the pores or openings between them are ultra-microscopic. When water is passed through the layer, suspended matter, bacteria etc. are caught on the surface and removed. The most common filter-aid material used in these filters is diatomaceous earth and these filters are termed diatomite filters.

In the filter-aid filter, a cylindrical shell is divided into two compartments by a plate containing a number of holes into which porous cylindrical tubes are set. These tubes are closed at one end and have the open end inserted in the plate and facing the upper compartment. Water enters the bottom compartment and passes through the filtering tubes (septa) on which is deposited a filtering mat or "precoat" layer of diatomaceous earth about one-tenth inch thick. Since the filter aid particles are microscopic and the pathway between even smaller, foreign matter is trapped on the filtering mat.

If the flow continues the mat tends to become clogged and the output decreases. To extend the effective filter run, a constant addition of filter-aid is made in a proportion to rate of flow. This is known as "body feed" which will extend filter runs up to 1000 per cent or more by continually building up the mat thus separating the particles of suspended matter and prevent total clogging of the openings. The dosage of body feed is critical; if just below optimum, the length of filter run will decrease markedly; appreciable increase above optimum produces only slight reduction in filter run.

Filter-aid filters have an air chamber. At the end of the filter run the effluent line is closed and air pressure allowed to build up in the air chamber. Next the influent valve is closed and a quick-opening back wash drain valve is opened. Pressure in the lower section is released suddenly which allows the trapped air in the top section to expand rapidly forcing water from the top section to at several hundred gallons per square foot per minute, thus literally blasting the filter cake loose. The filter is then drained and rinsed and a new precoat applied.



Modern civilization is placing an increasing burden on those responsible for supplying greater and greater quantities of pure water for home, recreation, and industry.

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Diatomite Filtration

by CONRAD E. LAWLOR,
Engr., General Filter Co., Ames, Iowa

IF YOU have been too busy the last few years to do much reading about this latest advancement in liquid filtration, this brief review may help you understand diatomite filtration as it is known today.

The diatomite filter (Fig. 1) is a straining unit, using diatomaceous earth as a filter membrane to remove materials in suspension in liquid.

What is diatomite? Geologists say it is the siliceous shells of tiny diatoms that once grew in great profusion on the earth. It has been said that there are some 10,000 different shapes (see Fig. 2) These diatoms form a very large deposit in California, where they lived some 5 to 20 million years ago. The chemists tell us these diatom skeletons are 89.7% silica. Fig. 2 is a micro-photograph of Johns-Manville's "Celite," one of the diatomites.

To the engineer, this material has a physical appearance of white face powder or finely milled white flour. It is very light and has great bulk per unit weight. Less than a half pound, (210 grams), has a surface area equal to the area of a football field, (45,000 sq. ft.).

Diatomite filtration has been proven by industry through years of use, but it has been only in the last eight years that the diatomite filter could be produced in quantity for filtration of water at a low cost to compete with sand filtration. Credit goes to the Armed Forces for first designing and using these filters during World War II. They were made to furnish potable drinking water under all field conditions. Small size and high filterability has now made them standard equipment with the U.S. Army. Organisms such as amoebic cysts and blood flukes could not be removed by rapid sand filtration. The diatomite filter does this job, even at high flow rates.

Filter Element and Membrane

In using diatomaceous earth for filtering liquids, it is necessary to use a filter element (Fig. 4) upon which a membrane, or filter cake, of the diatomaceous earth can be built. The particles of the filter aid must form a rigid skeleton or fine lattice structure on the filter element. This is capable of capturing the gelatinous or fine particles of the unfiltered liquid and yet leave passage-ways in the filter cake through which the liquid, freed of suspended matter, may pass at a rate and under such pressure differential as is economical. Fig. 3 illustrates these points, and it becomes obvious that proper design of the filter element is most important. It is correctly said that the element is the heart of the filter.

Hydraulically there are but two ways to filter liquid, namely by positive pressure; or, by negative pressure, i.e., suction. However, the vac-

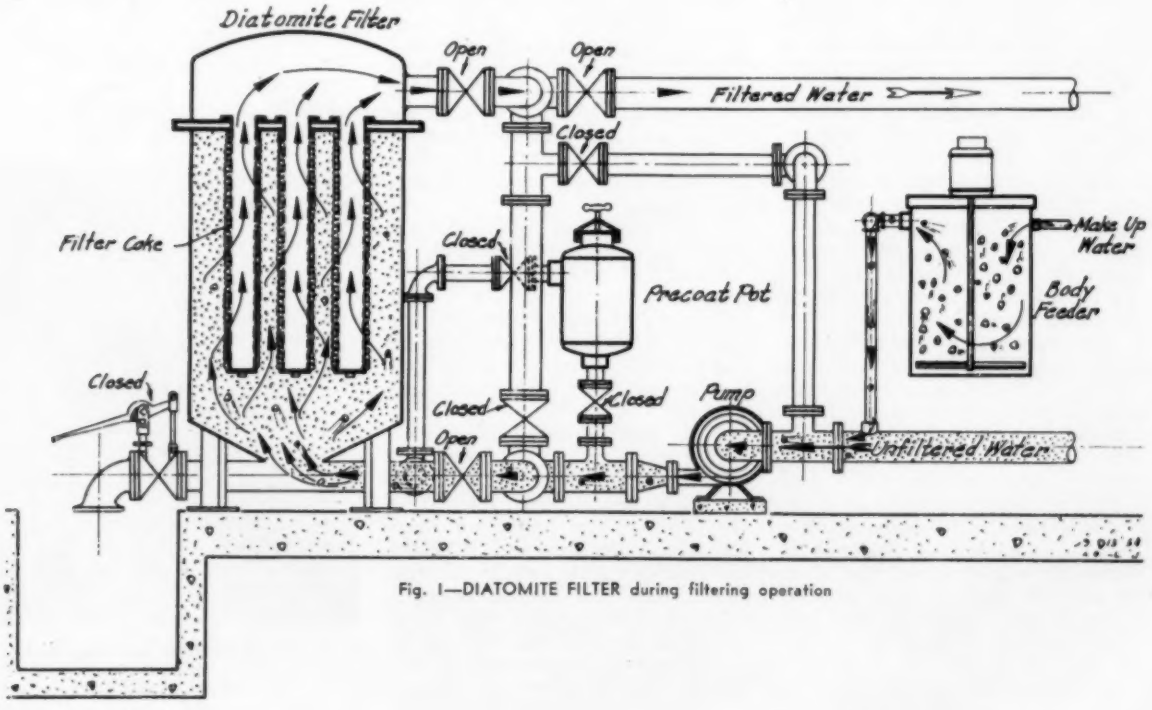

Fig. 1—DIATOMITE FILTER during filtering operation

uum type diatomite filter is handicapped by its short runs between backwashes.

The Filter

The pressure type diatomaceous earth filter consists of a number of

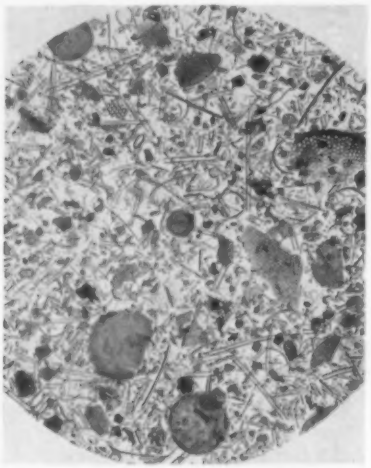

Fig. 2—DIATOMITE ("Celite" 512) under microscope

Note skeletons of siliceous diatoms in variety

cylindrical filter elements suspended from a plate within a pressure vessel —(see Figs. 1 and 4). The elements must have the characteristics of being durable, corrosion resistant, and must readily and easily clean during backwash. At the start of the filtering run, these elements are given a thin coat of diatomaceous earth, (called "precoat"), simply by introducing a charge of the earth into the filter inlet and then recirculating the water for several minutes. This coat of diatomaceous earth is the filter media which accomplishes the filtering result. As in sand filters, the dirt accumulates on the filter media, likewise, the loss of head through the media increases. This serves as the operators guide as to when it is time to backwash the filter.

The cleaning, or backwashing, is accomplished by surging the liquid backward several times through the filter to the point of backwash discharge. A quick opening valve (see Fig. 1 left side) is used in this operation and only a minute or two is required to completely clean the filter.

Some types of elements, because they have a tendency to plug with the diatomite, require compressed air to be properly cleaned. Most manufacturers of wire wound elements now recommend an air bump to clean the element. Some elements made of a more flexible material such as woven

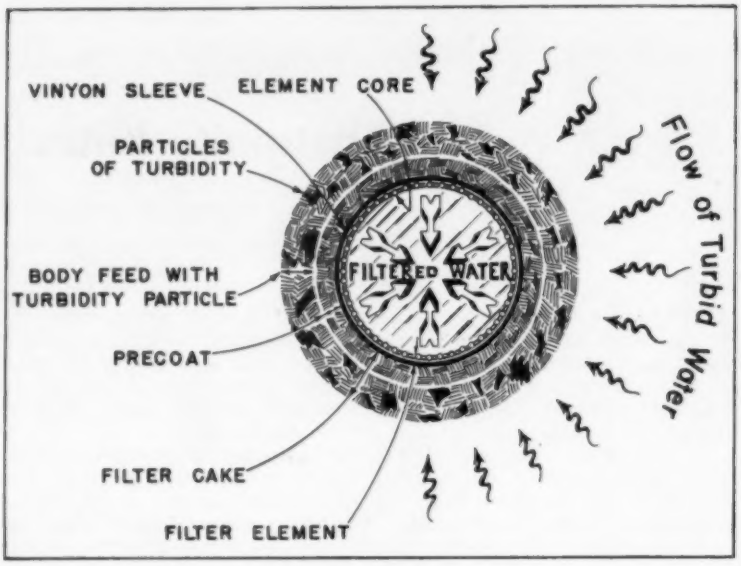

Fig. 3—FILTER ELEMENT in cross section

Shows relationship of core, vinyon sleeve, diatomite "precoat," and diatomite membrane, or filter cake. Body feed keeps filter cake porous.

cloth, (see Fig. 4) are more easily cleaned because of their ability to expand and contract with the flow of water. It is similar to the action of washing clothes in a washing machine.

Diatomaceous earth filters have been successfully used for a number of years in the sugar industry, and for clarifying ale, varnishes, beer, wines, soaps, dry cleaning fluids, and many other liquids. It is also employed to remove oil from condensate. The most recent employment of this equipment has been for filtration of swimming pool water. The sparkling clarity achieved with diatomaceous filtration, and also its compactness and lower cost, have made it increasingly popular.

Cost of this equipment usually runs a little lower than pressure filter installations of comparable capacity. Installation space is approximately one-third that required for pressure sand filters. Cost for chemicals, water and filter-aid is estimated to be comparable to the cost of operating sand filters.

Great care should be taken is selecting the filter for any given job. This is true because so far this method is in its infancy and, in fact, there are relatively few people who have had wide experience with diatomite filtration of liquids outside the laboratory. The new method is not a "cure-all" and diatomite filter plants should be carefully and conservatively engineered by experienced personnel in order to avoid prejudice against this method through misapplication.

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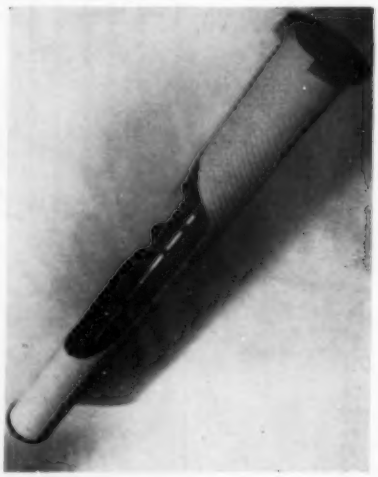

Fig. 4—FILTER ELEMENT of self-cleaning type

Woven element cloth is heavy duty DuPont acid resisting strainer cloth

Taste and Odor Control

TASTES and odors in water supplies are caused by either algae, decaying leaves and vegetation or by sewage and industrial wastes. Algal tastes are most prevalent and annoying.

Odors are determined by the "Threshold Odor Test" in which the odor is evaluated by smelling samples of water diluted with various amounts of odor-free distalled water. The Threshold Odor Number equals the volume of odor free dilution water divided by the volume of odorous water in that dilution above which the odor cannot be detected. A hot threshold number of more than two can usually be noticed by consumers.

Tastes and odors caused by algae can be controlled in two ways: (1) Preventive treatment by the use of copper sulfate added to kill off the algae before their concentration becomes great enough to cause severe odors and tastes. (2) Corrective treatment to remove or destroy odors already formed. The latter treatment includes aeration, chemical oxidation with chlorine dioxide, ozone or chlorine, and adsorption by activated carbon.

Chemical Treatment

In chlorine dioxide treatment, sodium chlorite solution is treated with a chlorine solution to produce chlorine dioxide (ClO_2), a strong oxidizing agent, soluble in water. A proportioning chemical feeder is used for the sodium chlorite solution and a chlorine gas feeder for adding the chlorine. A special generating column is used to mix the two solutions and produce the chlorine dioxide. The mixture from the generator is discharged into the water to be treated. It is the practice to add chlorine in a ratio of 1 part chlorine to 2 parts sodium chlorite in order to assure enough chlorine to lower the pH to 3.5 at which value chlorine dioxide is produced. Chlorine dioxide may also be generated by adding sulfuric acid to sodium hypochlorite and adding this mixture to a sodium chlorite solution.

Ozone for taste and odor control is generated in a special apparatus called an ozonator. Air, from which all moisture is removed, is passed through the tubes of the ozonator and subjected to a high voltage brush type electrical discharge. Approximately one per cent of ozone is produced. The ozonized air is discharged into the water under treatment, through a diffuser system. The ozone oxidizes the taste and odor compounds. Some difficulties may be experienced with this treatment as ozonation sometimes fixes certain tastes and odors and actually prevents their removal from the water.

The treatment of water with chlorine for the removal of tastes and odors is discussed in Section V.

Activated Carbon Treatment

By far the most popular corrective treatment is adsorption using activated carbon as the adsorbent. Activated carbon is a finely divided carbon with a highly adsorbent surface which will attract and hold these taste and odor compounds. Powdered activated carbon is most popular although granular carbon is used in beds in small installations.

Extremely small particles give a greater degree of surface exposure and the porous structure of activated carbon adds to this surface. It has been calculated that a single cubic inch of activated carbon has a total adsorption surface of 10,000 square yards. The fineness of the particles makes it possible to disperse the activated carbon throughout the water and for it to remain suspended for some appreciable period of time.

The adsorptive capacity of activated carbon is rated by its ability to adsorb pure phenol. The phenol value of a carbon is that amount of activated carbon in parts per million necessary to reduce phenol concentrations from 0.1 ppm to 0.01 ppm. Carbons with a phenol value greater than 30 are seldom acceptable for water treatment.

Powdered activated carbon is very finely divided and tends to be dusty when handled. To prevent dust it is fed from specially adapted chemical feeders, or it is mixed with water and fed as a slurry.

The most popular point of application is prior to coagulation although it may be added after coagulation. It is always added prior to filtration. When added ahead of coagulation higher doses are possible without adversely affecting filter runs, and at that point it will stabilize sludge in the settling basins.

Some operators like to add activated carbon just ahead of the filters but the dosage must not be high enough to decrease filter runs appreciably, and care must be used to prevent carbon passing through the filters.

The use of other chemicals also influences the point of carbon application and the amount of carbon required. If pH adjustment is practiced, the carbon should be added 15 to 20 minutes before the addition of lime or soda ash. Activated carbon should never be added with chlorine at the same point as the carbon will adsorb some of the chlorine and reduce its disinfecting power. These chemicals should be added at least 15 minutes apart in the treatment works. Which one should be added first depends on the local situation and condition of water being treated, but generally the carbon should be added first since it will remove odors which may be emphasized by chlorination.

The amount of carbon to use is determined by laboratory tests using odor free water and may run from 20 to 40 lb per mil gal. Where laboratory facilities are not available, carbon dosage determined by the "hit or miss" method, may be either over or under that actually required. The best method of determining the amount of carbon to add is to utilize the Threshold Odor Test. Samples of raw water are treated with increasing amounts of activated carbon in a technique similar to the coagulation jar test. Each sample is also treated with other chemicals which are used in the plant, in the same order and same time sequence as used in the plant. The threshold odor number is determined on each sample after treatment. The amount of carbon used to produce the desired threshold odor number in the samples, is used as a guide to the proper dosage of activated carbon in the plant.

Since activated carbon accomplishes better results in plant practice than on small scale laboratory tests, it is necessary to develop a relation between laboratory results and plant scale dosage. Sometimes as little as one half or one third of the laboratory indicated dosage is actually needed in plant operation.

Activated carbon has also been used effectively to control algae growths in small reservoirs and sedimentation tanks. Using the blackout technique activated carbon is added in sufficient quantity to prevent the penetration of sunlight into the water. Without sunlight, algae growth is minimized. This treatment is used only on sunny days.

Studies at St. Louis County Water Co. indicate that approximately one fourth pound of activated carbon will blackout 1000 sq. ft. Carbon added in this manner reduces the amount required for taste and odor removal in the treatment plant.

Taste and Odor Control in Small Water Plants

How the operator can solve problems caused by algae

By D. H. MATHESON
Chemist and Bacteriologist, Hamilton Filtration Plant, Hamilton, Ont.

THE difficulties attributable to algal growths constitute a perennial problem to the operators of treatment plants using surface waters as a source of supply. Each year these troubles must be overcome or endured. It is well to take stock, from time to time, of the preventive or ameliorative techniques that are available to minimize the plant difficulties and the public complaints arising from this recurrent phenomenon. In this paper, the subject will be considered particularly from the point of view of the small-plant operator who does not have expert technical advice at his immediate disposal, but who is expected, nevertheless, to know at least the possible courses of treatment that may be applicable to his situation.

The operator of a plant subject to algae troubles should make an effort to acquire some knowledge of these organisms. Of the many hundreds of algae species that occur in appreciable numbers in natural waters, comparatively few—perhaps a dozen or a score, at most—are regular causes of treatment plant difficulties. It is possible to learn to identify these with only a little training, as one learns to recognize the common wild plants and animals of the microscopic world. Simple counting methods can be used to indicate roughly whether the population density of an algal species is great enough to account for the operational difficulties that may be experienced.

Training of this nature is one of the most obvious advantages accruing from attendance at short schools for water works operators. It is highly desirable to know and recognize the causitive organisms rather than to treat blindly the symptoms observed in the plant. Some of the objectionable symptoms that are usually the effect of algae may occur in the complete absence of the organisms. It is evidently futile to take measures directed against algae if they are not the source of the difficulty.

The two most serious effects of algae in water treatment are interference with filtration and production of objectionable tastes and odors. The filter difficulties are generally due to a rather limited group of filter-blocking diatoms, although a few other organisms are occasionally present in sufficiently large numbers to be troublesome. The tastes and odors are caused by a wide variety of algae, the intensity and quality varying with the species concerned. Many organisms, especially the blue-green algae, produce more offensive odors when dead and decomposing than when alive.

Control of Algal Growth

Where the source of a water supply is a moderately sized body of stored water, either natural or artificial, direct chemical or biological interference in the cycles of growth of objectionable algae may often be advantageously undertaken. These control measures include reduction or limitation of the nutrient supply available to the organisms for their multiplication, the alteration of the physical conditions of the environment, such as the reduction of light intensity, and the planned destruction of algal populations by the use of algicidal chemicals.

The quantity of algae produced by a body of water—its productivity—depends on, among other things, the store of plant nutrients available to the organisms. These nutrients are contributed to the water from three main sources: the influent streams and the drainage from agricultural land; the addition of treated or untreated sewage; and the re-solution of mineralized nutrients from the decaying organic detritus on the bottom.

The access of nutrients in the influent streams and land drainage cannot be controlled unless the whole watershed can be managed and controlled as a unit. When this is possible, as it often is with watersheds in isolated, sparsely populated areas, significant limitation of plant food supplies may be achieved.

Domestic sewage contains large amounts of plant nutrients, particularly nitrogen and phosphorus, and may be expected to stimulate algal growths in the receiving waters. Ordinary sewage treatment does not remove appreciable quantities of these nutrients. Processes specifically designed to effect such reductions are of considerable interest at present.

Of the elements essential for algal growth, phosphorus is the one which is present in the waters in the smallest concentration, and which is therefore the one most likely to be depleted by algal growth, thus limiting the total algal crop. Sawyer[1] has recently pointed out that the phosphorus content of domestic sewage has probably doubled in the last 6 years, owing to the phenomenal growth in the use of synthetic-detergent compounds that contain much phosphate. It is quite likely, therefore, that sewage additions to water supplies will become increasingly more effective in causing large growths of algae than heretofore. Every care should be taken to minimize the access of nutrients through this agency.

Waters that are naturally high in nutrient level cannot be expected to show large decreases in plankton growth as the result of the removal of additional sources of nutrients.

In small presedimentation basins, control of the proliferation of algae may be obtained by restricting the entry of light. Covering such basins would no doubt be the ideal solution, but this is generally not economical for those of great size. The use of powdered activated carbon to reduce the penetration of light was instituted in the United States in 1939 and has attained wide popularity, especially throughout the midwestern states. The application of the carbon is quite simple; the quantities required are moderate and inexpensive; there is slight danger of ill effects through overtreatment; and some additional advantage may accrue through the adsorptive power of the carbon. There can be little doubt of the effectiveness of this treatment, as attested by its wide and continued use, but there is some uncertainty about the mechanism involved. It appears that the reduction of light intensity actually realized is not sufficient to account for the improvements noted in plant operation.

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Control of algae by the use of algicidal chemicals remains one of the standard methods of attacking this problem. Copper salts are still the only material widely employed, but research work is being prosecuted to find new, and perhaps more effective and specific, agents, especially in the field of organic chemicals. As the algae concerned are difficult to culture in the laboratory, it should not be too hard to discover some means of altering their natural environment to prevent their growth.

Chemical intervention in the biological system of the water should not be undertaken without due consideration of all the factors involved —the severity of the need, on the one hand, and the possible disadvantageous consequences, on the other. Treatment postponed too long may become inadvisable, owing to the deleterious effects of the release of a sizable quantity of organic matter after the destruction of a large algal population. A copper-resistant alga, generally one of the *Chlorophyceae,* frequently develops when a diatom population has been destroyed, and causes more difficulty than the original growth.

Copper sulfate is the salt most commonly used in algicidal treatments. Copper citrate, in the form of a proprietary preparation, appears to have some advantages under certain conditions, but there is little technical information available to demonstrate its superiority.

In relatively small basins, and, particularly, in filtered water reservoirs, chlorine has some value as an algicide and is effective against organisms that have a marked resistance to copper. The disadvantages include the difficulty in applying chlorine evenly to large bodies of water, the large amount required if the water has an appreciable chlorine demand, the rapid dechlorination that takes place when the water is exposed to sunlight, and the considerable danger of causing an increase in taste and odor through the formation of chloro compounds. Some of these deficiencies can be avoided with chloramine.

Copper and chlorine together are more effective than is either alone, and a combination of chlorine, copper, and ammonia, first used by Harold in England in 1934, has lately been employed by Smith at Richmond, Va., for the control of algae and other organisms in open service reservoirs and in the distribution system.[3]

In France, a novel process of "electrocution" is used for controlling the growth of algae in water applied to slow filters. An a-c field of approximately 90 v per inch is established between electrodes in a narrow channel through which water flows at approximately 1 fps. The algal cells are killed by the passage of the current through the water and do not multiply in the water on the filters. The process is used in one small municipal plant and has been proposed for a new one.

Algae and Filtration

When the source of supply is a river or a large lake, or when, for some reason, control of the algal growths in the water supply is not feasible, the purification plant must treat the algae-containing water as it comes to the plant. Removal of the algae by efficient coagulation and sedimentation is the obvious procedure, but it is attended with great difficulties.

The addition of coagulant frequently appears to make filtration more difficult, as the natural buoyancy of the algal cells prevents rapid sedimentation of the floc, and the filter load is increased. Many have reported that continued use of coagulants was practically impossible. Baylis and Gerstein[3] consider that certain algae add toughness to the flocculated particles deposited on the filter and thus tend to form a tenacious and impermeable mat on the sand surface.

Increasing the coagulant dose sometimes helps to overwhelm the buoyant effects of the algae with an enormous amount of floc. This method is obviously very expensive, especially when it is considered that water containing algae is usually very clear and requires little coagulant for clarification. It is not unusual to find that increasing the coagulant dose does little to improve filtration.

The addition of material such as clay to produce artificial turbidity aids in sedimentation by increasing the density of the floc and has been so used on several occasions. Baylis has offered the useful suggestion that, in waters like the Great Lakes, which are saturated with calcium bicarbonate, the addition of a small quantity of lime would cause the precipitation of an additional amount of calcium carbonate and economically provide a heavy material to weight the floc.

Activated carbon, when added before or with the coagulant, is effective in producing a more settleable floc, as has been demonstrated at Chicago.[3] Utilizing carbon in this manner for lengthening filter runs is an expensive procedure, but, as its use is required only for a comparatively short time during the year, the annual cost of water treatment is not unduly increased. The convenience of using a material that is already at hand, and for which feeding and handling equipment is already provided, makes it preferable to clay as a coagulant aid.

The improved coagulation that silica sols provide under certain circumstances has been used to a limited extent in attempts to remove algae.

The heavier floc produced by coagulation with iron salts makes these materials attractive in coagulating waters containing algae. Where plant-scale experiments have been performed, the advantages of iron coagulation have usually not been great, however, and have been overbalanced by the additional cost and the difficulties in handling and application. Alum has ultimately been found preferable as a coagulant.

The use of copper sulfate applied with coagulants is frequently mentioned as a means of improving filter operation. With motile organisms or those that tend to disintegrate when killed, the treatment appears to be effective, but, with diatoms, the dead cells do not seem to be removed by coagulation any better than do the living.

Prechlorination generally appears to be the most effective method of aiding coagulation in the presence of algae, particularly when the organisms are susceptible to disintegration by the chlorine. At Windsor, Ont., short filter runs caused by diatoms were much improved by prechlorination, especially when a free chlorine residual was produced.

Algae-containing waters that are to be treated on slow filters are frequently passed through coarse rapid filters first, to remove the greater portion of the algal load. In England, a unique process of microscreening has been developed commercially to pretreat these waters, in place of the bulkier roughing filters.[4] The screening membrane, a stainless steel fabric with apertures as small as 35 μ, is mounted on a continuously rotating drum, through which the water flows. The screen is continuously washed with approximately 1 per cent of the treated water. The larger diatoms are almost completely filtered out, and the overall removal is better when the water contains large amounts of suspended matter, because the heavy mat formed on the screen increases its effectiveness. When water supplies are free of color and turbidity and require

treatment only for removal of plankton, microstraining may possibly be used alone.

Sanchis has recently discussed the development of diatomite filters designed solely for the purpose of removing plankton from otherwise clear waters.

Operators of conventional rapid sand filters, when treating clear water containing only algae, find it best to use no coagulant. If the sand is not too coarse, most of the diatoms and other algae are removed, and if the turbidity of the raw water is not too high, preferably about 5 ppm, an acceptable quality of output can be maintained. Frequent short washes are sufficient to remove the algae from the filter, and the use of an above-normal quantity of wash water is a more economical way of removing the algae than is additional chemical treatment. This procedure has been used with satisfactory results at Hamilton, Ont., for more than 15 years. The turbidity of the filter effluent is kept below 1 ppm, a concentration that is not high enough to cause complaints. The wash water used during the algae season amounts to approximately 5 per cent, but, for short periods, it has risen as high as 10 per cent.

Tastes and Odors

Algae, living or dead, often most conspicuously affect water supplies by the production of tastes and odors. These vary in intensity and in quality from the not too objectionable fresh-vegetable and aromatic odors of many living algae to the highly offensive pigpen odor of decaying blue-green algae. As little is known about the exact nature of the chemical substances in the water that are responsible for the production of tastes and odors, progress in the development of ameliorative treatments has been on a purely empirical basis.

Chlorination in the usual moderate dosages generally has the effect of intensifying the odors of algae. Hale[8] attributed this fact to the freeing of the "essential oils" on the death and disintegration of algal cells. Some organisms liberate substances that, on chlorination, produce tastes highly medicated in character and practically indistinguishable from chlorophenol derived from industrial wastes.

From the standpoint of palatability, disinfection of water with chloramine is desirable because it minimizes the intensification of odors and, in general, aids in the removal of the odorous substances by activated carbon.

Superchlorination is effective against algal tastes and odors in varying degrees, depending on the algal species, the chemical properties of the water, and the peculiarities of the individual treatment plant. Superchlorination is particularly effective against the odor of *Synura*. The odors of diatoms, *Anabaena*, and *Dinobryon* are reduced, especially on long contact, but are not completely removed. Superchlorination requires much more careful chemical control for its successful operation than other treatments do, and it may produce highly odorous nitrogen trichloride in waters containing a large quantity of albuminoid ammonia.

Chlorine dioxide is now widely used for the control of tastes and odors and is very effective in removing chlorophenolic odors of industrial origin. Removal of strictly algal odors is accomplished with greater difficulty and by substantially higher dosages. Chlorine dioxide is the most effective treatment for removing the odors attributed to actinomycetes.

Ozone is the strongest oxidant commercially available for water treatment plants. It has attained its widest use in France, where a total of more than 160 mgd is ozonated. It is used there primarily for its bactericidal properties, but its oxidizing power for color and odor is recognized. The large ozonation plant at Philadelphia was designed primarily for taste and odor reduction, as, in the limited detention period possible, it was not feasible to control treatment by free residual chlorination. Ozone effected similar oxidation after a few minutes of detention. Ozonation requires much more expensive equipment than chlorination, a considerable deterrent to its use in the United States and Canada, where there is no strong aversion to the employment of chlorine. Ozone, however, completely avoids the danger of intensifying odors by the production of chlorinated compounds.

No method of taste and odor removal has attained widespread acceptance as rapidly as activated carbon. This treatment has outstanding advantages over chemical methods. It is effective, at economically justifiable dosages, against producing tastes and odors. Thus, it is not necessary to determine the exact cause and source of the offending material before treatment can be prescribed, whereas other methods may be applicable only to a limited class of substances. Carbon is simple and easy to apply. Although dosages of 2-5 ppm are usually effective, enormously greater amounts can be applied without danger of causing serious harm. And by no means the least of its advantages is the fact that its use appears to meet with the water consumers' approval, which is seldom accorded to other chemicals.

The principal problem in the use of activated carbon is the determination of the most economical dose. Sometimes very large doses are required, amounting even to 100 ppm, but these may be justified because the need for such treatment is usually of short duration. The efficiency of carbon treatment depends upon a number of factors. Adsorption is generally poorer at a higher pH. Chlorination may aid or hinder adsorption, depending on the nature of the odorous substance, and carbon is usually more effective with chloramine than with chlorine. In filtration plants, carbon may be used before coagulation, in which event coagulation may be improved and the sludge accumulating in the sedimentation basins stabilized. Carbon may also be added after coagulation, giving the floc an opportunity to remove some of the offending material first. Suspended carbon carried to the filters is very effective in the adsorption of odors, although some shortening of runs may occur.

Limited use is made of activated carbon in water where no filtration is provided. At several places in the United States where impounding reservoirs or small lakes have been heavily infested with algae, copper and carbon were used to remove the growth without producing objectionable tastes. In Winnipeg, Man., up to 2.5 ppm has been used in service reservoirs without causing difficulties, although higher doses are noticeable to the consumer.

Conclusion

The regular seasonal pulses of algae may cause serious difficulties in the operation of water purification plants. Although troubles may be unavoidable, they should not be considered insuperable. The battle against algae can be joined at several points.

The concentration of algae in the incoming water may be lowered by avoiding unnecessary fertilization of the supply, or by interfering with the multiplication of the organisms by physical or chemical means. Once in the plant, the algae can be re-

moved by improving the efficiency of coagulation. Microscreening offers interesting possibilities. Filtration without coagulation, and with the abundant use of wash water, is a cheap and effective procedure when applicable. A variety of treatments to combat offensive tastes and odors are available. These range from the powerful oxidants designed to destroy the odorous materials chemically to adsorbent carbons that remove the offending substances physically.

The deleterious effects of algae can be overcome. It is more often a question, depending on the severity of the conditions, of what expenditure is justified.

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Methyl Purple vs Methyl Orange In Alkalinity Titrations

By RALPH W. FREY

Chemist, Washington Suburban Sanitary Com., Hyattsville, Md.

RECENTLY there has come on the market an indicator known as methyl purple, with suggestions that it might be substituted to advantage for methyl orange in alkalinity titrations.

Most chemists know of the unsatisfactory behavior of methyl orange as an indicator. Its use frequently creates a desire for something that gives sharper and more contrasting color changes; requires less time; does not involve so much indecision and whose results are not so dependent upon the moods and color-consciousness of the individual.

Table I

METHYL PURPLE VS METHYL ORANGE

(River and Branch Waters)

Station	Collection Date	Kind	Alkalinity-ppm Methyl Purple(1)	Alkalinity-ppm Methyl Orange(1)
1	1/26/50	grab	15	19
2	"	"	17	21
3	"	"	51	56
4	"	"	45	50
5	"	"	41	41
6	"	"	60	59
1	12/14/50	"	21	22
2	"	"	21	23
3	"	"	58	59
4	"	"	26	29
5	"	"	29	31
6	"	"	31	33
11	11/21/50	"	10	11
15	"	"	12	14
16	"	"	18	18
17	"	"	17	18

(1)—With 4 drops of phenolphthalein.

Standard Methods for the Examination of Water and Sewage, 9th Edition, American Public Health Association, specify under "Alkalinity of Water" and also "Alkalinity of Sewage" the use of methyl orange, *or its equivalent.* Appreciating the opportunity that methyl purple might offer in replacing methyl orange in the alkalinity determination procedure strictly comparable titrations of sewage, chiefly sanitary, and of non-potable waters were made with these two indicators.

Table II

METHYL PURPLE VS METHYL ORANGE

(Sewage Treatment Plant No. 1)

Sewage	Collection Date	Kind	Alkalinity-ppm Methyl Purple(1)	Alkalinity-ppm Methyl Orange(1)
Raw	11/12/50	24-hr.	96	92
Primary	"	"	102	98
Final	"	"	96	96
Raw	11/16/50	24-hr.	140	140
Primary	"	"	126	128
Final	"	"	116	114
Raw	11/19/50	24-hr.	124	128
Primary	"	"	146	140
Final	"	"	144	152
Raw	11/23/50	24-hr.	120	124
Primary	"	"	142	144
Final	"	"	104	106
Raw	11/26/50	24-hr.	84	80
Primary	"	"	88	84
Final	"	"	88	86
Sewage Treatment Plant No. 2				
Raw	11/13/50	grab	184	188
Primary	"	"	204	216
T.F.E.	"	"	168	172
Final	"	"	140	140
Raw	11/17/50	"	152	152
Primary	"	"	212	220
T.F.E.	"	"	140	132
Final	"	"	136	128

(1)—With 4 drops of phenolphthalein.
T.F.E.—Trickling Filter Effluent.

The results here presented need no elaboration. The end-point carried to a distinct purple with methyl purple is pleasingly sharp and far superior to that of methyl orange. The figures given show definitely that methyl purple can be substituted for methyl orange, a substitution that will prove most gratifying.

Table III

METHYL PURPLE VS METHYL ORANGE

(Aged Sewage[1] - Treatment Plant No. 1)

Sewage	Collection Date	Kind	Alkalinity-ppm Methyl Purple(2)	Alkalinity-ppm Methyl Orange(2)
Raw	12/ 2/50	24-hr.	116	114
Primary	"	"	94	98
Final	"	"	88	90
Raw	12/ 5/50	"	98	94
Primary	"	"	104	98
Final	"	"	108	102
Raw	11/30/50	"	122	116
Primary	"	"	120	114
Final	"	"	120	116

(1)—Aged at 22°-26°C in open jar, then made to original volume with distilled water. First two groups aged 48 hrs.; last group aged 72 hrs.
(2)—With 4 drops of phenolphthalein.

Chlorine Container Handling Truck

Adaptation of Light Utility Truck, Specially Rigged for Distributing One Ton Chlorine Containers to Up-Sewer Chlorinating Stations

By FRANK H. MILLER

Chief Engineer, Hampton Roads San. District, Norfolk, Va.

THE truck here pictured is a low bed, six wheel stake truck regularly used for system service work. It has been equipped for the handling of ton containers of chlorine transported from treatment plant container stock to up-sewer chlorinating stations. Advance arrangements for utilization of the equipment required no change at the Hampton Roads Sanitation District Commission's Boat Harbor Sewage Treatment Plant, where a stock pile of some 20 containers can be maintained and swing hoist equipment was available. At the three up-sewer pumping stations, where chlorine is applied, the truck can be backed into position for easy unloading. A fence has been constructed around the cylinder storage area for safety.

Adaptation of the truck for such chlorine container handling consisted of the following:

(1) A drum type winch was bolted to a steel bearing plate and mounted at the front end of truck bed. Winch handle was lengthened and a side steady-bearing provided at the right edge of truck bed.

(2) Runners of 2" x 6" boards were provided on each side of the bed to give even spread bearing for the container, and built up stops were bolted in place in position giving best weight distribution on truck. Pin stops are provided behind the container to hold it in place—(see close-up view).

(3) Skids were constructed of 6" x 8" heart pine 12' long, the truck ends of which were supported and attached to truck bed by heavy (½" x 2½") strap iron hangers. These straps were carried about 2' along the bottom of the skids and bolted in place, bent up along the truck end of the runners and over to form hangers, which can be hooked into the bed tail channel. This channel was reinforced with ⅛" plates to assure adequate support.

(4) Dead men ties were bolted into bed tail channel for fastening two sides of spread sling.

(5) Wire rope (½") was constructed with spread V yoke to attach to truck bed with V being terminated in a single strand at about 8' from truck bed tail channel. This V sling assures stability at upper position of cylinder on skids and until cylinder is far enough down skids to assure steady bearing on both skids.

(6) For transportation of skids a rack was built up just behind the cab so that skid hangers could be inverted, hooked in place and suspended over cylinder during haul.

In operation the chlorine container is placed at bottom end of skids, with one or both ends on small block so that the loading sling can be pulled under the cylinder. Sling yoke is then attached to dead men. Then by turning winch cylinder is rolled up the skids and on to truck bed. On this flat surface it is readily rolled into position on bed by hand. Although two men usually work together, it is possible for one man alone to carry out the entire operation with no heavy lift or pull required.

Unloading is merely a reverse of this procedure, with the placing of cylinders largely controlled by positioning of truck.

Most of the equipment used was salvaged from odds and ends on hand. Fabrication was effected in the Commission's shop, with only about one man-day being required for the work. The original idea for this equipment was that of John D. Coenen.

LIGHT utility low-bed truck equipped to handle ton chlorine containers
Safety loaded container on truck and close-up of loading winch and container in position.

TRUCK loading or unloading sequence
A one man operation, with winch and loading cable of ½ in. wire rope

Chlorine Packages

by V. W. LANGWORTHY

Development Engr. Omega Machine Co., Providence, R. I.
Formerly, Research Chemist, The Chlorine Institute, Inc., New York, N. Y.

LIQUID chlorine was introduced as an article of commerce in 1909, and developments in its handling and application have progressed steadily. Caution has been the watchword, with careful attention being paid to the lessons learned through numerous valuable, and sometimes bitter, experiences.

It is the purpose of this series to delineate, in a practical way, the present day handling techniques which use equipment evolved from cautious advancement in the art of chlorination.

Chlorine Packing Units

Anhydrous liquid chlorine is available in packages of several sizes, all of which are pressure vessels of steel construction and are equipped with safety devices. Loaded packages have about 12 per cent gas space at 68° F. to allow expansion of the liquid contents when exposed to higher temperatures. Internal inspection of returned packages is routine: outlet valves are removed and overhauled after each trip and all packages are pressure-tested at regular intervals.

Chlorine Cylinders

Consumers of chlorine used for sanitation are familiar with 100 lb., 105 lb. and 150 lb. packages, properly referred to as cylinders. The Interstate Commerce Commission specification number, serial number, producer's insignia, date of last hydrostatic pressure test and the tare weight are stamped into the shoulder of each cylinder.

Cylinder valves have brass bodies and Monel metal stems; these valves have been standardized by The Chlorine Institute, Inc. Each chlorine cylinder valve is equipped with a fusible plug safety device designed to melt between 158° F. and 165° F. (Fig. 1).

Chlorine cylinders, empty or full, should never be dropped or permitted to strike each other with any force.

Ton Containers

Liquid chlorine is also available in one-ton packages, properly referred to as ton containers. The Interstate Commerce Commission specification number, serial number, producer's insignia, date of last hydrostatic pressure test, water capacity and tare weight appear on each container.

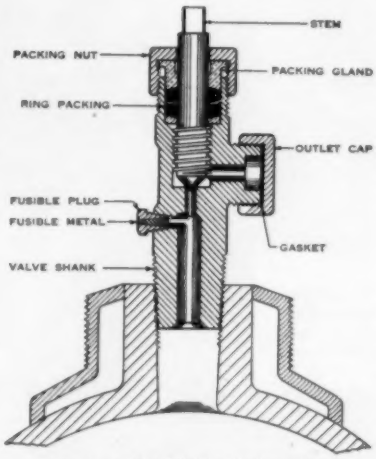


Fig. 1—CHLORINE cylinder valve
This is the Chlorine Institute standard cylinder valve with screwed type fusible metal plug. There is also a standard poured type plug.

Each ton container is equipped with two Chlorine Institute standard ton container valves (Fig. 2). Valves for ton containers are *similar* to the valves used in cylinders, but they differ in that ton container valves have a larger internal hole and *do not* have a fusible plug safety device (Fig. 3). Safety precautions for ton containers are observed by utilizing six fusible plugs per container. Three plugs are located in each end of a container, spaced 120° apart. The fusible metal has been designed to soften or melt at a temperature between 158° F. and 165° F.

Chlorine containers, empty or full, should never be dropped or permitted to strike each other with any force.

Tank Cars

The largest common chlorine shipping packages are single unit railroad tank cars of three different capacities: 16, 30 and 55 tons. These consist of a steel tank, four inches of cork insulation and an outer steel shell. Four angle valves are located in a dome centered on the top of the car. The valves are constructed of forged steel, with Monel stems and seats (Fig. 4). Outlet threads of the valves are 1-inch female standard tapered pipe threads. Tank cars have a spring loaded safety valve located at the center of the dome. This device is gas tight at or below 180 lbs. pressure (gauge), and pops at 225 lbs.

Liquid chlorine is unloaded through the two angle valves located on the axial center line of the tank; eduction pipes leading to these valves are fitted with rising ball check valves designed to shut when the rate of flow of liquid chlorine is 7,000 to 8,000 pounds per hour.

Gaseous chlorine may be unloaded through two angle valves located at right angles to the length of the car (on 55 ton tank cars, one of these gas valves has been replaced with a second safety valve).

The U. S. Coast Guard has authorized the shipment of chlorine by tanks on barges especially designed for this service. A few producers make use of this means of conveying comparatively large quantities of liquid chlorine. This package has not been used in the sanitation field.

Handling Chlorine Cylinders

(100, 105 and 150 pound capacity)

Transportation of full and empty cylinders usually is accomplished by

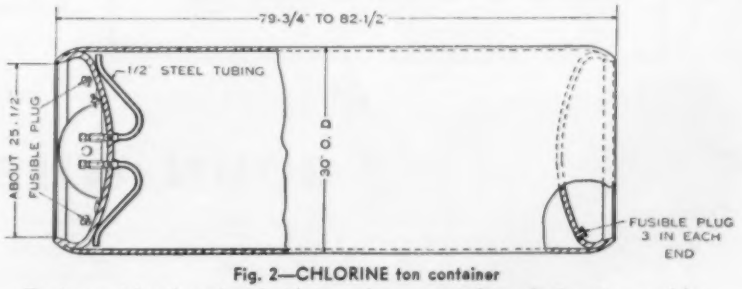
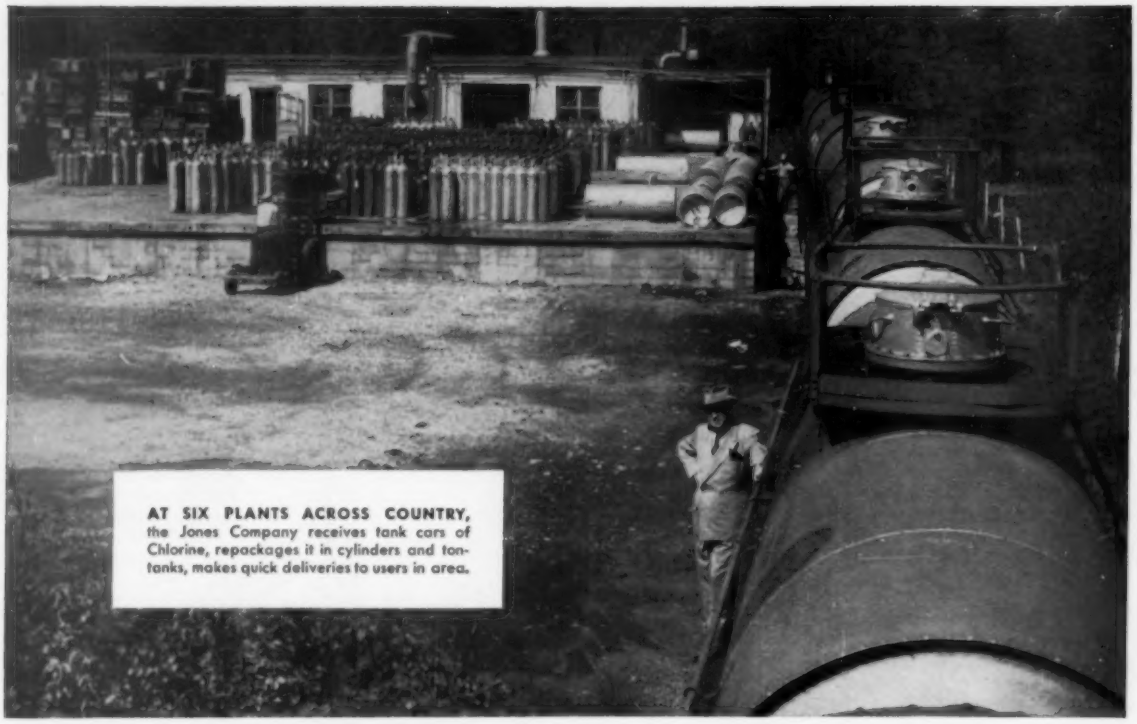


Fig. 2—CHLORINE ton container
The ton container is equipped with two valves connected to eduction pipes, and has three fusible metal plugs in each end.



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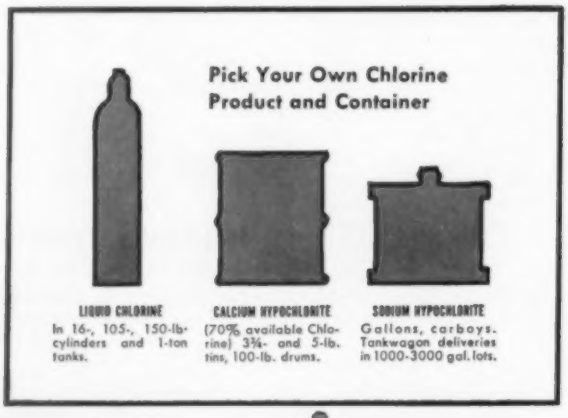
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Tele—North Dade 6-6288
or Dial 81-6-6288

truck or rail shipment. In the interests of safety, unloading docks should be at truck or car bed level. Manhandling of cylinders is dangerous and use of hand trucks is recommended. The use of a well-designed hand truck, properly balanced, preferably with a clamp support at least two-thirds of the way up the cylinder, is considerably more economical than the consequence of a possibly fatal mishap (Fig. 5).

A partial listing of firms offering hand trucks of this type is the following:

The Fairbanks Co.,
393 Lafayette St.,
New York 3, N. Y.

The Lansing Co.,
Lansing, Michigan.

Colson Corp.,
Elyria, Ohio.

Hamilton Truck and Caster Corp.,
Hamilton, Ohio.

Cylinders should be stored in a cool place, in an upright condition, away from dampness, ventilators, elevators and walkways. Valve protection caps should be kept in place until immediately before use. Never lift cylinders by the cap, and do not use a lifting magnet or sling in handling cylinders. Cylinders should be used in the order they are received, since it is possible for old valve packing to become dry enough to permit escape of chlorine gas. It is desirable to support cylinders securely during chlorine withdrawal.

Connection to the cylinder valve outlet may be made by either a clamp-and-adapter (Figs. 6A and 6B) or a union connector (Fig. 6C). In either case, inspect the inner surfaces of the joining parts and always remove old gaskets and foreign material. When a full cylinder is connected, a new gasket of standard material should be used. Standard gasket materials are 3% antimony lead, or Garlock 900 or equivalent.

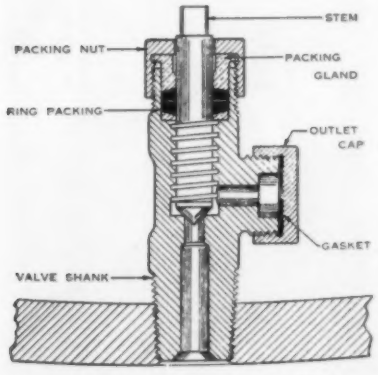

Fig. 3—CHLORINE ton container valve
This is the Chlorine Institute standard ton container valve; it has no fusible metal plug.

Open cylinder valves slowly: one complete turn of the stem in a counterclockwise (left hand) direction opens the valve sufficiently to permit maximum discharge. Do not use a wrench longer than 6 inches for operating a cylinder valve. Leaks may be detected by holding an ammonia moistened cloth near all connections. When this is done, the presence of chlorine will be evident if a white cloud (ammonium chloride) is formed (Fig. 7).

The practice of compounding cylinders (manifolding) to increase *gas* withdrawal rates entails increased caution when putting full cylinders in service. A good precaution to observe is a check of each outlet connection by partially opening and immediately closing the cylinder valve to insure that solid connections have been made.

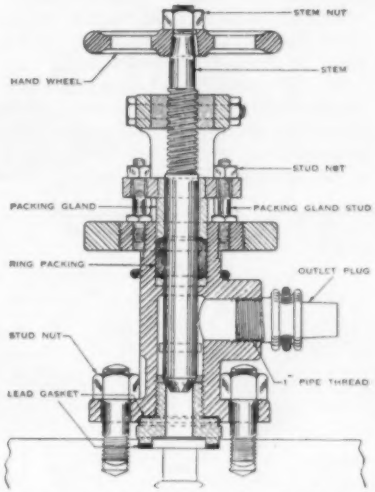

Fig. 4—CHLORINE angle valve for tank cars

Consumers removing *liquid* chlorine from cylinders are cautioned that manifolding cylinders for liquid chlorine withdrawal should NOT be attempted.

Handling Chlorine Containers

(2,000 pound capacity)

Transportation of full and empty ton containers usually is accomplished by rail. The ton multi unit railroad tank car has been developed to meet the needs of consumers using chlorine in excess of 30 tons per year. The car consists of an underframe on which are mounted 15 detachable containers, each containing 2,000 lbs. of liquid chlorine. The car is classified as a tank car and freight is charged only on the 15 tons of liquid chlorine. The empty containers on returning underframes travel on a freight free movement. It is possible in certain locations to obtain ton containers via truck delivery.

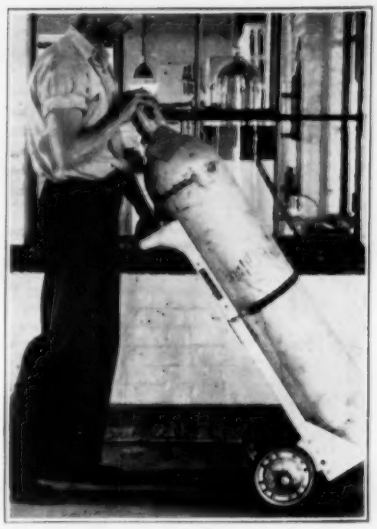

Fig. 5—HAND TRUCK for chlorine cylinders
Note rubber tires and strap to secure the cylinder during movement.

The advantages of using chlorine from ton containers are well known: less handling, connecting and disconnecting. The fact does exist, however, that ton containers are bulky to handle. They may be handled safely, provided adequate equipment is available for unloading, storing, using and re-loading empty containers.

Unloading full containers may be accomplished by means of a specially designed lifting clamp* (Fig. 8). The clamp is used in combination with a hoist on a trolley or a jib boom. Ton containers which must be trucked from the siding to the storage area should be placed on saddles on the truck and clamped down to prevent shifting and rolling. Cradles should also be provided in the storage area, with overhead hoisting equipment for transporting containers to and from the scale room (Fig. 9).

It is good practice to store ton containers in a cool place, away from dampness, ventilators, elevators and walkways. Containers should be stored on their sides, with valve protection hoods in place. Do not store chlorine containers in the vicinity of combustible or flammable materials.

As with chlorine cylinders, it is advisable to use full containers in the

*One source of supply for these clamps is Mansaver Industries, Inc., 3105 East St., New Haven, Conn.

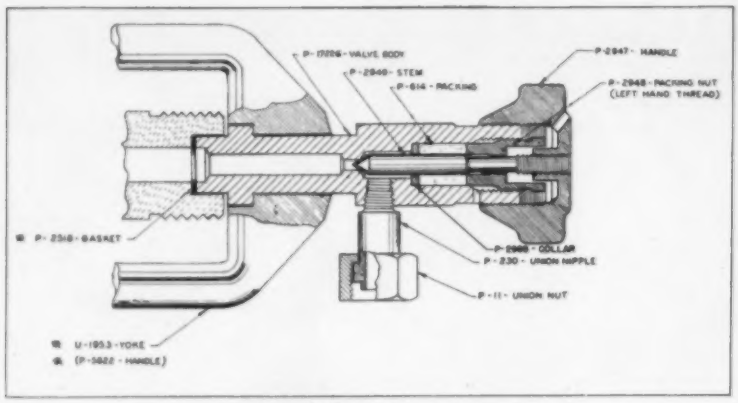

Fig. 6A—CYLINDER VALVE outlet connection
This is a clamp-and-adapter or yoke type connection of auxiliary valve to chlorine cylinder valve.

Fig. 6B—CONNECTION to cylinder valve
Note proper size of wrench (6-in. long) for tightening yoke clamp and operating cylinder valve.

order they are received. *Never* tamper with fusible plug safety devices.

Connection to the proper container valve outlet may be made either by a clamp and adaptor or a union connector. The proper valve depends on whether liquid or gaseous chlorine is to be withdrawn (Fig. 10). Placement of the container on scales must be such that the two valves are positioned vertically. Thus eduction pipes within the container will conduct liquid chlorine to the lower valve and gaseous chlorine to the upper valve.

In making connections, gasket surfaces should be thoroughly inspected and cleaned, a new gasket of standard material should be used for each connection. Outlet threads on the valves of containers are NOT tapered pipe threads. Make certain that the threads on the appliances and unions are the same as those on the outlet valves, and never force connections that do not fit.

When a firm connection has been made, open the container valve slowly, being alert for a possible chlorine leak. Never use a wrench longer than 6 inches for operating a container valve. It is usually possible to eliminate a gas leak around the valve stem by tightening the packing nut.

If the practice of compounding (manifolding) ton containers is followed, to increase withdrawal rates, increased vigilance must be observed in connecting and disconnecting.

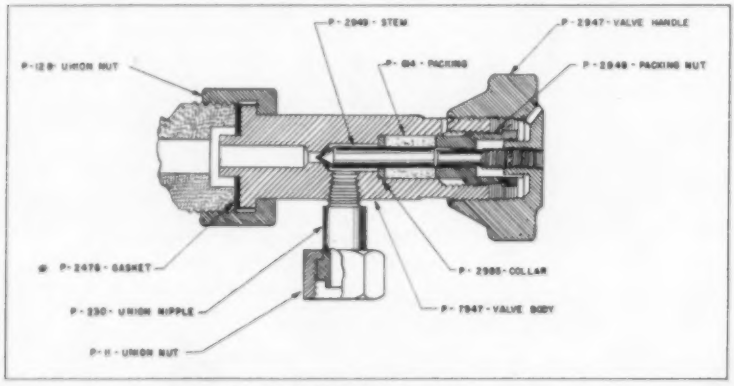

Fig. 6C—CYLINDER VALVE outlet connection
This is a union type connection of the auxiliary valve to the chlorine cylinder valve.

When is the Chlorine Cylinder or Ton Container Empty?

Three observations are commonly employed to indicate that chlorine cylinders or ton containers are becoming empty. Loss in weight is the most dependable indicator of the amount of chlorine remaining in a cylinder or ton container.

Loss in Weight

Producers and repackagers load precise weights of chlorine in the various packages, and tare weights are carefully checked. Therefore, scales used by consumers in conjunction with chlorine feeding should be in good operating condition. Close observation of weight loss should always be made, and this applies especially when approaching the point where a change to full packages must be made.

Pressure Drop

Two other indicators, while not as useful as loss in weight, do serve to warn that cylinders or ton containers are becoming empty. One is the observation that the gauge connected to the chlorine gas transmission line shows a pressure drop, and the other is evidence of a vacuum break (sucking air) caused by lowering of pressure in the chlorine supply system.

Both of these indicators provide warning in advance of depletion of cylinder or container contents. Note that the chlorine gas pressure gauge does not measure the volume or weight of chlorine remaining. Pressure exerted by confined chlorine gas depends on the temperature: theoretically, one pound of chlorine will,

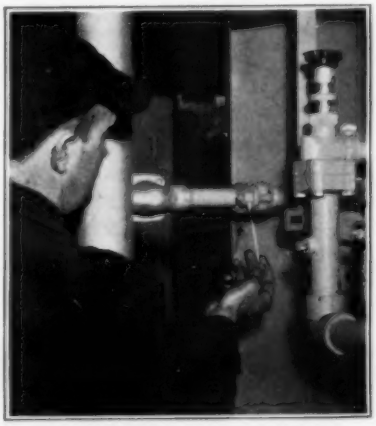

Fig. 7—TESTING for a chlorine leak
A cloth or swab moistened with ammonia is held near each connection in the chlorine gas line.

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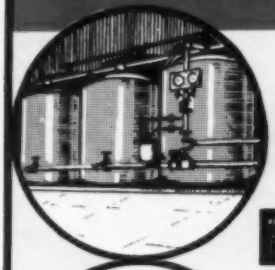
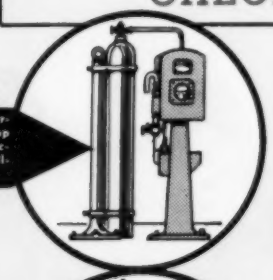


"CHEMCO" Vacuum type chlorinator type M-1 up to 300 lbs. capacity per 24 hrs. bulletin S-300-1



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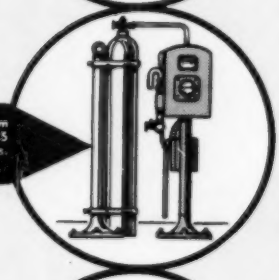

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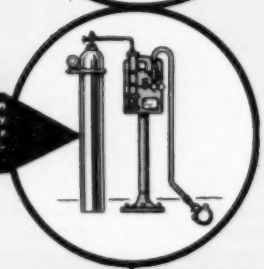

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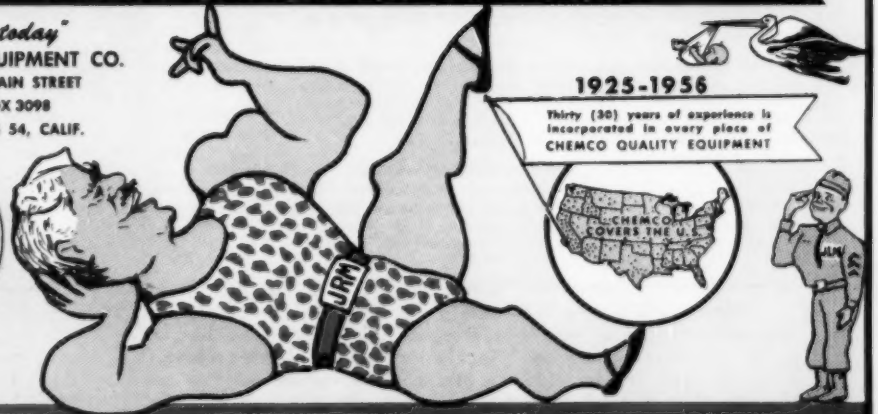
EVERYTHING FOR THE SWIMMING POOL SINCE CHEMCO 1925



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CHEMCO in 1955-56 is celebrating the 30th year since its founding by the present owner in October, 1925. Chemical Equipment Company of California — trade mark CHEMCO — has become synonymous nation-wide for "EVERYTHING FOR THE SWIMMING POOL." Therefore, our 30th year Fiesta celebration will extend from May, 1955 to April, 1956.

CHEMCO is not going into ecstasies about the wonderful virtues of its management, that has survived depressions and wars, in the traditional glowing fashion of anniversary blurbs. But rather, we are honoring certain employees and departments by the cartoon above, which we explain, in part, below.

The female contingent is represented by our oldest in point of service, but still beautiful, Dixie, who guards the treasury and writes the checks. Dixie comes from the South—Suh!—and we caricature her in hoop skirts and the crinoline of the Old South, and a few corkscrew curls, for is not the South supposed to be Democratic?

Next is Seem our machinist, whose first name is Basil, whose education in Russia is equivalent to M.I.T. in this country. His father was "High Brass" in the Russian Imperial Railway System. Basil fought with the White Russians clear across the Siberian Railway to Vladivostok, a fishing boat the hard way to Seattle. He is caricatured with fur, boots and spurs, perhaps Cossack Style, carrying the caliper as Shop Superintendent. He represents our shop service, installation and construction section, as Shop Superintendent.

Next is Mac, the only real full-blooded, true Scotsman. Chief Engineer and Chief Estimator, he with the sharp pencil indicative of his profession, illustrating that oft posed question, "What does a Scotsman wear under his kilt?" The answer—NOTHING.

Next is JRM, the writer, President ● Founder ● Legally Sole Owner ● Sometimes Janitor ● who has spent all his life chasing customers. Those diamonds shown on my vest front—if I own them—I don't know where they are. But I have, for over 30 years, been more or less successfully chasing customers, who I sincerely hope have been satisfied, happy and contented that JRM sold them. Supplying "Everything For The Swimming Pool" should make them happy as we explain below.

CHEMCO'S PLEDGE TO OUR CUSTOMERS

Chemco will supply the entire purification equipment, deck equipment and underwater lights for your swimming pool, under one responsibility and jurisdiction, as simple and foolproof as we can make it, not overloading any one piece of equipment, but by taking it all in one lump sum, taking a lesser profit on each, but by virtue of taking it all, render you the necessary expert service, correlating the equipment so that it functions as it should, which makes a profitable venture for us, and a satisfactory installation for our purchasers and users.

at a given temperature, exert as much pressure as will 2,000 pounds. It is emphasized that low readings of the chlorine pressure gauge merely indicate the probability of lowered tank contents.

Vacuum Loss

On chlorine feeders of the visible vacuum type, "bubbling" of air into the bell jar may indicate reduced pressure in the chlorine system. Depending on the feed rate, "bubbling" may proceed for varying lengths of time before a full cylinder or container must be placed in service. Chlorine feeders utilizing a rotometer, which measures gaseous chlorine flow, will perform in much the same manner, but rotometer readings will tend to drop off.

It will be noted that accuracy of chlorine dosage suffers when "bubbling" occurs or rotometer readings are unsteady. Changes to full chlorine cylinders or containers should be made promptly when this condition is coincident with loss of weight readings. It is obvious that economical usage precludes efforts to evacuate the last traces of gaseous chlorine from cylinders or containers.

Producers of liquid chlorine do completely evacuate chlorine from all returned packages. This is essential, because all cylinders, containers and tank cars are inspected internally prior to refilling. Another step includes removal, reconditioning and replacement of all chlorine valves.

Empty chlorine cylinders and ton containers should be removed from service immediately, tagged as empty and placed in a separate area to prevent possible confusion with full packages. Chlorine producers recommend prompt return of all empty packages as well as return of full packages considered to be in excess of adequate inventory.

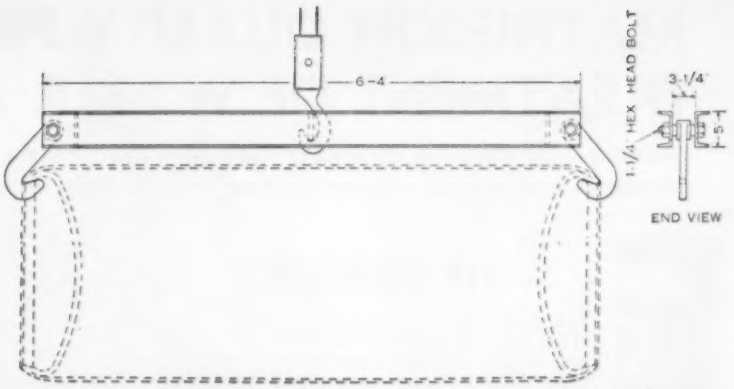

Fig. 8—LIFTING CLAMP designed for chlorine ton container handling

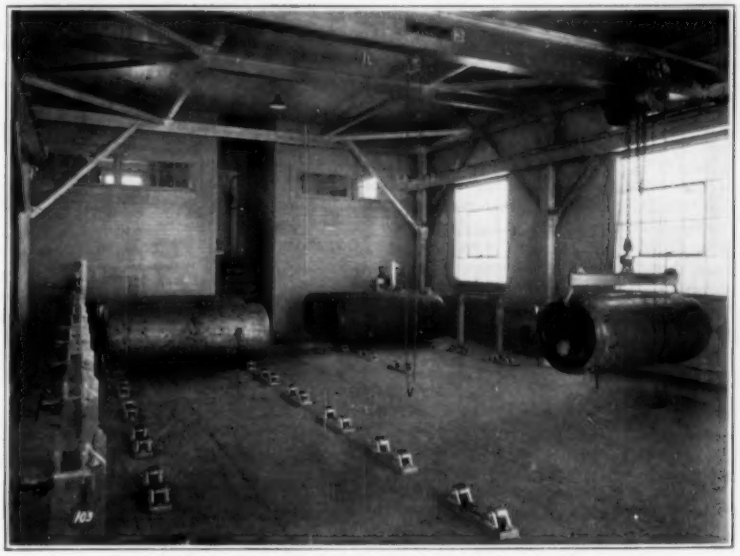

Fig. 9—STORAGE and handling facilities for chlorine ton containers
Lifting clamp is raised by overhead 3-ton hoist. Roller cradles facilitates positioning and connecting containers to discharge line.

Fig. 10—CONNECTED chlorine ton container
Gaseous chlorine is withdrawn from the upper valve. See Fig. 2 also.

Procedures involved in handling liquid chlorine differ from those in handling chlorine gas only insofar as vaporization is concerned. Liquid chlorine is withdrawn from the ton container through the lower outlet valve and is conducted to an evaporator of the type commercially available from equipment manufacturers. Vaporization of the chlorine is accomplished by heating within the evaporator. The gas is delivered to the metering equipment under constant temperature and pressure. Visual or orifice type flow meters may be employed, with or without recording equipment.

Handling Single Unit Tank Cars (16, 30 and 55 tons)

The necessity for caution in handling tank cars containing chlorine has long been recognized by the producers and by the Interstate Commerce Commission. Accordingly, those concerned with safe handling of the several tank car sizes must observe requirements which appear in sections of Agent H. A. Campbell's Freight Tariff No. 8*. Full legal requirements which must be met in unloading chlorine tank cars may be found in Sections No. 74.560 through No. 74.563 of Freight Tariff No. 8.

In addition to compliance with I.C.C. regulations the consumer, in order to assure maximum safety,

*Issued by H. A. Campbell, Agent, Bureau of Explosives, 30 Vesey Street, New York 7, N.Y.

MATHIESON QUALITY PRODUCTS FOR TREATMENT OF WATER AND WASTES

TREATMENT OF RAW WATER • CLARIFICATION OF TURBID AND COLORED SUPPLIES • REMOVAL OF TASTES AND ODORS • WATER SOFTENING • STERILIZING NEW EQUIPMENT • CLEANING SUPPLY EQUIPMENT AND INSTALLATIONS • EMERGENCY CHLORINATION

HTH GRANULAR

The following outstanding properties of HTH have gained wide acceptance for the product by water works operators and others using HTH in water treatment: dependable strength of at least 70% available chlorine, high stability that maintains the product at full strength even after months of storage at summer temperatures, low calcium chloride content that eliminates hygroscopic tendencies, rapid and complete solubility of the active ingredient in water.

The available chlorine in HTH is in the form of true calcium hypochlorite, which is $Ca(OCl)_2$. When consideration is given to the light-weight, non-returnable containers in which HTH is shipped, its available chlorine per pound of gross weight exceeds that of liquid chlorine in the 100- and 150-lb. cylinders. Moreover, its use involves none of the hazards that attend the handling and use of liquid chlorine. It is little wonder, therefore, that water works men avail themselves of this convenient, safe source of available chlorine wherever practicable.

The 5-lb. cans of HTH Granular, packed 9 to the case, are particularly convenient for sanitization of newly laid pipelines, isolated water supplies and at locations where transportation of the chlorine carrier is a troublesome factor. For continuous or emergency hypochlorination of water supplies, the 100-lb. drum of HTH Granular may be a more economical unit. In determining the more desirable package, however, consideration should be given to the advantage of keeping a product not immediately needed in sealed 5-lb. cans rather than in a 100-lb. drum that is frequently opened.

HTH TABLETS

For convenient handling in many water treatment applications, HTH is also available as HTH Tablets. This product is simply HTH in the form of compressed, easy-to-handle tablets which dissolve slowly and provide a continuous source of available chlorine over an extended period of time.

HTH Tablets are made wholly of dependable HTH and contain 70% available chlorine the same as the time-tested granular product, HTH Granular. The tablets are stable and dust-free and thus offer an exceptionally safe and convenient means of handling, measuring and storing available chlorine. HTH Tablets are packed in 100-lb. drums and in cases of twelve 3¾-lb. cans.

HTH TABLET HYPOCHLORINATOR

By use of the HTH Tablet Hypochlorinator the convenience offered by HTH in tablet form can be combined with accurate metering and feeding of hypochlorite solutions. This equipment, specifically designed by Mathieson to dissolve HTH Tablets and to dispense the resultant hypochlorite solutions, provides a convenient and efficient method of feeding available chlorine at rates which can be accurately controlled and quickly varied to cover a wide range of operating demands.

The HTH Tablet Hypochlorinator is of practical design, compact construction, and attractive appearance; it is easy to install and very simple to operate. Moreover, HTH Tablet chlorination eliminates all measuring and weighing operations, and requires no preparation of stock solutions. The HTH Tablet Hypochlorinator is engineered to give long-time reliable service. Initial cost is low, and since the unit operates with no moving parts, maintenance and upkeep expenses are almost negligible.

HTH Tablets and the HTH Tablet Hypochlorinator can be applied successfully and economically in most cases where continuous chlorination is desired. Such uses include chlorination of industrial wastes, industrial sewage, potable water, ponds, swimming pools and spray towers, and the feeding of hypochlorite solutions in dairies, canneries, bottling plants and other food and beverage plants.

SODIUM CHLORITE

Chlorine dioxide (ClO_2), is produced at the point of use by the interaction of chlorine and sodium chlorite ($NaClO_2$). The reaction takes place in a simple mixing chamber or solution generator, and the reagents may be (1) solutions of chlorine and sodium chlorite or (2) solutions of HTH, acid and sodium chlorite. The dilute chlorine dioxide solution thus formed is fed directly into the water for taste and odor control and for disinfection.

Mathieson Sodium Chlorite Technical is a dry, flaked material containing 130 per cent available chlorine. It is non-hygroscopic, extremely soluble in water and very stable both in dry form and in solution. Packed in 100-lb. drums and 25-lb. pails.

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Activated Alum—the only alum designed exclusively for use in the field of water and sewage treatment—contains finely ground natural silicates, providing a free-flowing, less hygroscopic product of porous structure and higher alumina content. Activated Alum is used and preferred by some of the largest municipal water works in the U.S.A. Packed in 100-lb. four-ply paper bags.

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A special moisture-free alkali for water treatment, fused at 1,800° F. and cast in ½-lb. slow-dissolving cakes. The cakes have a purity and rate solution particularly desirable for pH control of swimming pool water and general industrial water treatment. Shipped in 100-lb. bags.

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Industrial Chemicals Division

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Fig. 11—TANK CAR angle valve connected to deliver liquid chlorine
The angle valve (see Fig. 4) is located inside car dome; pipe wrench is to be no longer than 18 inches. Discharge line has flexible loop at car end.

should familiarize himself and his employees with the general recommendations of his chlorine supplier. Helpful suggestions are contained in technical service department chlorine bulletins, The Chlorine Manual** and published reports from operators experienced in tank car handling.

Typical of the legal requirements which must be met in order to unload chlorine from single unit tank cars is the necessity for a consumer to: acquire a private railroad siding; allow only reliable persons properly instructed and made responsible for compliance with regulations to perform unloading operations; place caution signs so as to warn of the operation in progress; detach unloading lines whenever unloading operations are suspended; have the car attended by a responsible person whenever the car is connected to an unloading device; be sure that complete unloading is followed by tightening all valves, removal of unloading connections and tightening of all other closures.

Producers have made general recommendations which amplify the legal requirements and provide further techniques in safe handling of tank car chlorine. Typical of these recommendations are: the derail protection of cars being unloaded; limit to 18 inches of the pipe screwed into a tank car discharge valve; use of a pipe wrench no longer than 18 inches in making tank car connections; provision of a flexible arrangement at the tank car end of the discharge line; use for chlorine service of extra heavy black iron or steel pipe with clean, sharp threads; painting of chlorine piping a distinctive color (yellow is most common) to guard against mistakes in identifying pipe lines; and provision of approved gas masks for emergency use.

The legal requirements and general recommendations cited are admittedly incomplete, the intention being to suggest that many precautions must be taken in handling single unit tank cars —and additional procedures are required to limit sources of potential hazard. Fig. 11 illustrates details of a connection being made to a single unit chlorine tank car at a sewage treatment plant.

Summary

Packages containing liquid chlorine must be treated with the respect which they deserve, in order to insure safety. It might be said that experience, not personal, but the type learned from others, is the best teacher of proper procedures to follow in handling chlorine.

**Copies are available from The Chlorine Institute, Inc., 50 East 41st St., New York 17, N.Y.

Chlorination to Restore Aqueduct Capacity

San Diego finds programmed chlorine application effective and economical

By LEE STREICHER

Chief Chemist, Metropolitan Water Distr. of Southern Calif., LaVerne, California

DOMINANT among the factors which are reflected in the past history and which control the future growth of southern California is the struggle for water. Located in a semi-arid section of the United States, this region has too little rainfall to provide for the needs of its agricultural, industrial and urban areas. Only by drawing upon the once tremendous supply of underground water accumulated over thousands of years has the phenomenal growth of this area been made possible. With the continuing growth in population and industry, the draft on the underground water reserve has increased until it now exceeds the replacement by many million gallons of water each day. Where feasible, storage reservoirs have been constructed in an effort to conserve and utilize to a maximum the limited and variable water supplies available from the upland and mountain streams. These have long since proved wholly inadequate to meet the constantly increasing demands for water. Even in San Diego County, where for many years the waters impounded during wet seasons provided satisfactorily for the demands during subsequent dry periods, the present use of water is about 25 per cent greater than the safe yield of these impounding reservoirs.

The only logical solution to this problem lay in the importation of sufficient water from a dependable, adequate and reasonably close source to provide for present needs and those of the forseeable future. The Colorado River was such a source.

Metropolitan Water District Formed in 1927

In 1927 the Metropolitan Water District Act was adopted by the California legislature and in 1928 the Metropolitan Water District of Southern California was organized to bring in the water of the Colorado River. The voters of the cities comprising the District authorized a bond issue to finance the construction of the now famed Colorado River Aqueduct and all necessary appurtenances to bring Colorado River water to these cities and contiguous areas, the whole project to be paid for solely by the taxpayers and water users of the District. Construction of the aqueduct was started in 1932, and the first water was delivered in Los Angeles metropolitan area in June, 1941. [1, 2]

Wartime augmented demands pinpointed the critical water shortage in the San Diego area. By agreement with the other Southern California agencies concerned, the city and/or county had already been apportioned an annual quota of 112,000 acre feet of Colorado River water, but no facilities were available for delivery of any of this to the vicinity of San Diego. In December of 1944 President Roosevelt approved an emergency appropriation for construction of an aqueduct from the west portal of San Jacinto tunnel (on the Colorado River Aqueduct) to San Vicente reservoir of the San Diego water syster—(Fig. 2). Although some delay in construction was occasioned by an acute shortage of labor and materials, the initial flow of Colorado River water passed through this vital link into San Vicente reservoir on November 24, 1947. Design and construction of this aqueduct was under Navy supervision.

On December 17, 1946, the corporate area of the San Diego County Water Authority officially became annexed to the Metropolitan Water District of Southern California. The District assumed payment of one half the cost of construction of the San Diego Aqueduct and, upon completion

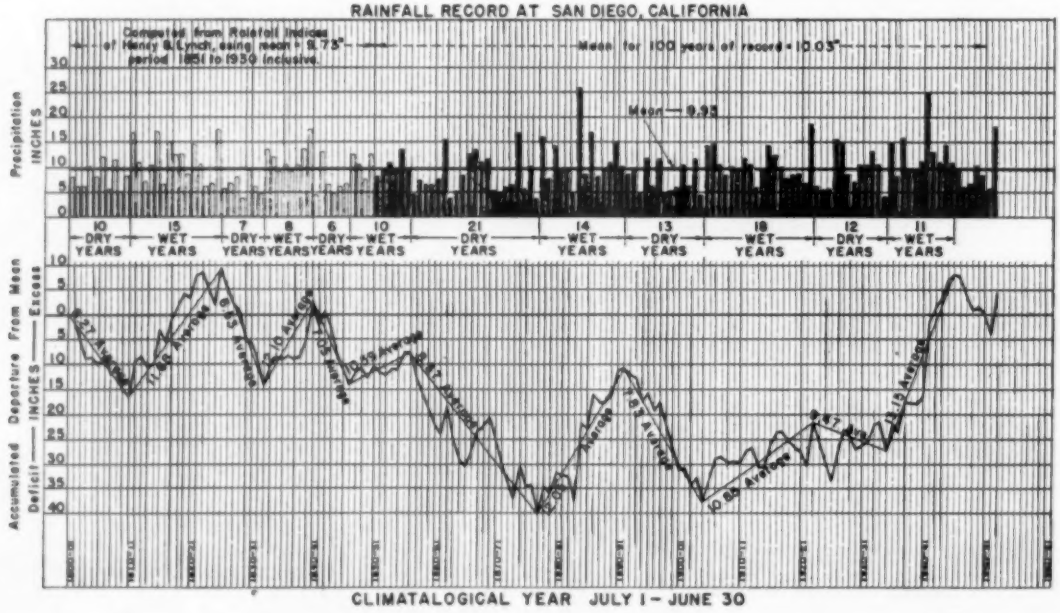
RAINFALL RECORD AT SAN DIEGO, CALIFORNIA
Computed from Rainfall Indices of Henry S. Lynch, using mean = 9.73" period 1851 to 1950 inclusive.
Mean for 100 years of record = 10.03"
Mean — 9.95
Precipitation INCHES
10 DRY YEARS
15 WET YEARS
7 DRY YEARS
8 WET YEARS
6 DRY YEARS
10 WET YEARS
21 DRY YEARS
14 WET YEARS
13 DRY YEARS
18 WET YEARS
12 DRY YEARS
11 WET YEARS
Accumulated Departure From Mean Deficit — INCHES — Excess
CLIMATALOGICAL YEAR JULY 1 - JUNE 30

Fig. 1—RAINFALL record at San Diego, Calif., 1800-1953 reveals 100 yr. mean of but 10.03 inches.

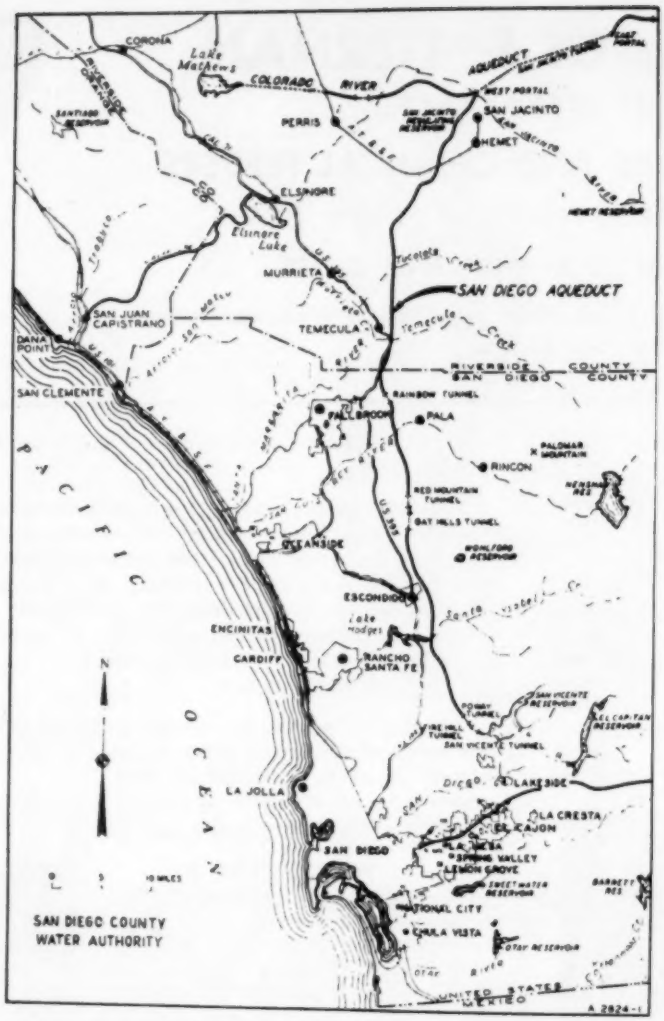

Fig. 2—AQUEDUCT of San Diego County Water Authority
Point of chlorine application San Jacinto Regulating Reservoir near head of aqueduct.

of the line, took over operation of the northerly one half of the system.

Aqueduct Design Features and Operating Characteristics

The first barrel of the San Diego Aqueduct (Fig. 2) designed for an initial capacity of 85 cubic feet per second, is 71.1 miles long and consists of 4.4 miles of 72-inch diameter tunnel; 2.0 miles of 96-inch and 12.4 miles or 72-inch diameter reinforced concrete pipe; 21.8 miles of 54-inch and 28.8 miles of 48-inch diameter precast concrete pipe; 1.1 miles of steel pipe; and a regulating reservoir with available storage of 1400 acre feet 0.6 mile in length located two miles from the takeout at San Jacinto tunnel. When the aqueduct was designed, it was intended that the capacity would be increased ultimately to 165 c.f.s. Because of the subnormal rainfall in this area in recent years and the increasing demand for water, the second barrel is already under construction.[3]

Early in December, 1947, extensive tests of the carrying capacity, operating characteristics and hydraulic properties of the aqueduct were made. The results of these tests were very satisfactory and indicated that the maximum carrying capacity of the line was more than 20 per cent above the normal design figure.

Loss in Capacity a Serious Matter

Because of the great need for water in the San Diego area, every effort was made to operate the feeder at its maximum capacity. Flow at a rate of approximately 104 c.f.s. was maintained continuously until the middle of June, 1948. On June 14th it was observed that the water level was unusually high in the outlet structure at the San Jacinto Regulating Reservoir. An inspection revealed that the water was backing up in the aqueduct and that the freeboard at each of the open structures along the line was noticeably reduced. Within a few days it was necessary to reduce the rate of flow to less than 96 c.f.s. in order to keep some of the vent structures from overflowing. It was suspected that biological growths within the pipe were responsible for the reduced carrying capacity, and microscopical examination of several samples of deposit removed from a number of points along the line confirmed this.

Chlorination Tried as Remedial Measure

Chlorination of the water entering the San Diego Aqueduct, in an attempt to remove and control bacterial growths and biological films, was started on July 7, at which time the flow in the line was about 94 c.f.s. Two 1-ton cylinders of chloride were connected by a pipe manifold from which chlorine gas was fed into the aqueduct through a 2-inch rubber hose weighted at the discharge end to keep it submerged. The point of application was just below the outlet gate from San Jacinto Reservoir. On the basis of earlier chlorine demand tests which had been run on natural Colorado River water, an initial dosage of 3.5 to 4 ppm of chlorine was applied in order to carry a free-chlorine residual of about 1.0 ppm to the last open structure on the District's portion of the feeder. This rate of chlorine application was continued for 6 days, after which it was reduced to about 2.5 ppm. By July 19 (12 days of chlorination) the reservoir discharge had been increased to 99 c.f.s. When a carrying capacity of 100 c.f.s. was attained eight days later (July 27), no further increases in flow were sought. The freeboard at the structures continued to increase, however, and by November 1 was back to normal for 104 c.f.s. flow.

Continuous Chlorination for Combined Chlorine Residual

On October 16 a chlorinator was installed at the reservoir outlet (Fig. 3) and the chlorine dosage was reduced to between 0.5 and 0.6 ppm. This dosage was selected as a result of chlorine demand tests which had shown that the maximum combined-chlorine residual could be obtained from this rate of chlorine application to the water in San Jacinto Reservoir at that time. The chlorinator was a Wallace & Tiernan solution feeder

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FREE RESIDUAL CHLORINATION

Recent developments in water works practice show that bacteria practically cease to exist where Free Residual Chlorination, as accomplished by the Break-Point Process, is employed. Such chlorination assures the production of free available chlorine residuals which have a high killing potential. In many plants bacterial control by the Break-Point Process has been augmented with additional benefits such as improved coagulation, increased color removal, elimination of algal conditions, reduced chemical costs and increased length of filter runs with a resultant saving in wash water.

TYPE MASV AUTOMATIC SOLUTION FEED VISIBLE VACUUM CHLORINATOR

Where unusual or extreme fluctuations in water or sewage flow are encountered, the Type MASV meets the chlorination requirements. It embodies all the advantages of automatic proportioning of chlorine feed, and automatic starting and stopping with the outstanding features of the Visible Vacuum Control Chlorinator — rugged construction, simplicity of operation and low maintenance costs.

Type MASV Automatic Visible Vacuum Chlorinator

THE W&T HYPOCHLORINATOR

W&T Hypochlorinator

Chlorination of small water supplies involves problems which the W&T Hypochlorinator is especially designed to meet. This equipment feeds either calcium or sodium hypochlorite in solution form and is furnished in three types.

The Electrically Operated type is particularly useful for small pumped water supplies. Since water pressure furnishes the major part of the operating power, the cost of electricity is but a few cents a day. Automatic Water Operated Hypochlorinators automatically proportion the chlorine solution to the flow of water and are especially adapted to small gravity water supplies with wide variations in flow.

The Belt Driven unit is a sturdy, dependable unit for use where electric power is not available or where operation is to be synchronized with pumping equipment driven by gasoline engine or other similar motive power.

WT Silactor

WT SILACTOR ®

The WT Silactor (pronounced SILL-actor) provides a system for the continuous production of activated silica with chlorine. Raw materials—chlorine and sodium silicate—are withdrawn directly from their own containers without handling or dilution. All chlorine used in the WT Silactor is available for the normal functions of chlorine, such as killing bacteria and algae, or for the oxidation of iron, manganese and other oxidizable material.

DRY CHEMICAL FEEDERS

For the application of dry chemicals, Wallace & Tiernan offers a complete line of feeding equipment. The Types MO, MOF and MOI Dry Feeders include such advantages as positive agitation, easy calibration and accurate feed over ranges of from 0.5 to 200 pounds per hour, depending upon the chemical used.

CONVENIENCE

W&T is represented by a service staff prepared to discuss the proper equipment for any chlorination problem.

Current literature on the many phases of chlorination, ammoniation and dry chemical feeding is available on request.

with a rated capacity 1000 pounds of chlorine per day. An 8-inch diameter hole was cut through the top of the 72-inch I.D. concrete pipe about 20 feet downstream from the outlet gate from the reservoir, and a concrete chimney with a 12-inch I.D. opening was built over this hole to provide access to the surface. A 2½-inch steel pipe was installed in this chimney, terminating at a point about two feet above the invert of the aqueduct line. This structure is pictured in Fig. 4. The rubber hose carrying the discharge from the chlorinator was passed through the steel pipe, so that the chlorine solution might be applied as far below the surface of the water as practicable. No diffuser was used.

At intervals of one to three months, chlorine-demand curves were prepared from tests run on the reservoir water samples. On the basis of these data, the chlorine dosage was varied, as necessary, to maintain the maximum obtainable combined-chlorine residual. The chlorine dosage required to maintain this condition ranged from 0.5 to 1.1 ppm, depending upon the quantity of nitrogenous material present in the water—(Fig. 5). Occasionally, particularly in midsummer when water temperatures were at a maximum, the carrying capacity of the feeder would start to decrease slowly despite this continuous chlorination. Happily, application of chlorine at a dosage of about 3 to 4 ppm (Fig. 6) for 18 to 24 hours always restored the freeboard at the structures and the capacity of the line. For 10 months during the period from April 1951, to March 1952, a flow rate of more than 106 c.f.s. was maintained in the San Diego Feeder, a peak of 106.7 c.f.s. being attained. Comfortingly, this was fully 25 per cent more than the designed capacity of the line.

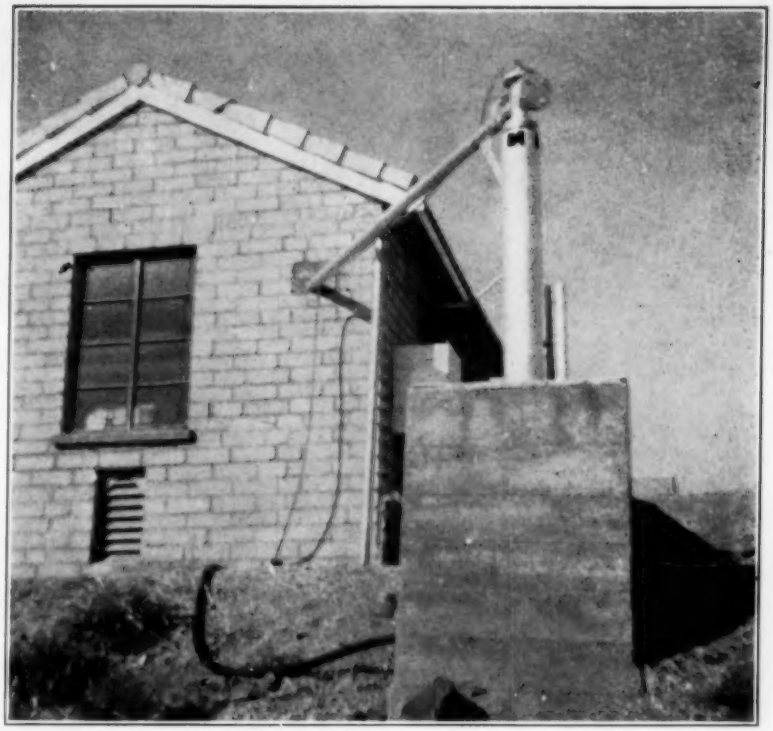

Fig. 4—CHLORINE inlet arrangement on aqueduct

Chlorine gas at regulated pressure is conveyed through ⅝" plastic hose which connects into 2" "Uscolite" pipe leading to chlorine inlet structure.

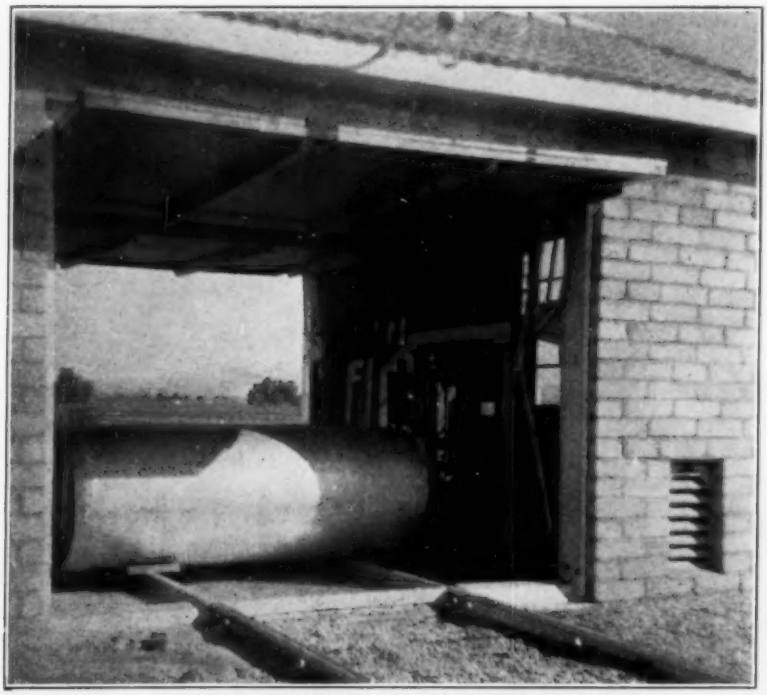

Fig. 3—CHLORINATING station at San Jacinto Reservoir

One-ton chlorine container on platform scale; W. & T. chlorinator in far corner on right.

Early in the summer of 1951 chlorination practice at San Jacinto Reservoir was modified to the extent that the higher dosage of chlorine (3 to 4 ppm) was applied at more frequent intervals but for only 2 to 6 hours during each period of application. Between these periods normal chlorination to the "hump" point on the breakpoint curve was still continued—(Fig. 5).

So successful did this procedure prove to be that it was decided to experiment with the use of intermittent high-dosage chlorination alone, without continuous low-dosage chlorination. While plans for this were in progress, the article by Jackson and Mayhan[4] appeared in *Water & Sewage Works*, describing the experience at Little Rock in maintaining supply line capacity by chlorination. This article confirmed the idea that contin-

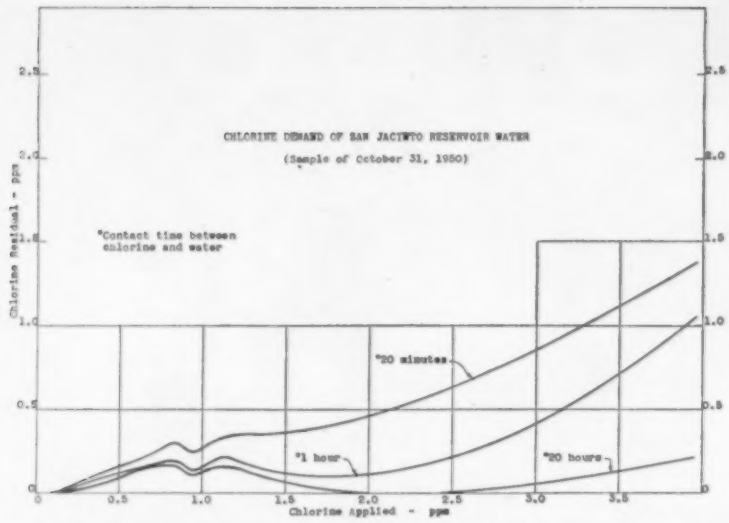
CHLORINE DEMAND OF SAN JACINTO RESERVOIR WATER
(Sample of October 31, 1950)
*Contact time between chlorine and water
Chlorine Residual - ppm
Chlorine Applied - ppm
*20 minutes
*1 hour
*20 hours

Fig. 5—CHLORINE DEMAND curves for San Jacinto Reservoir water Oct. 31, 1950

uous chlorination might not be necessary.

Intermittent Chlorination for Free Residual

Late in the fall of 1951 continuous chlorination at the San Diego Feeder was discontinued, and the program of chlorinating for 2 hours every day at a chlorine dosage of 2 to 3 ppm was instituted. When this schedule proved highly satisfactory, the frequency of chlorination was further reduced. At present, chlorine is applied twice each week, 100 pounds being used during each two-hour period of application. This is equivalent to a chlorine dosage of about 2.2 ppm for 2 hours at the current 100 c.f.s. rate of flow in the feeder. Aqueduct capacity is being very satisfactorily maintained, and freeboard at all the open structures is at a maximum. During the hottest summer months it may sometimes be necessary to increase the dosage temporarily—possibly to 150 pounds or even 200 pounds for 2 hours twice each week. Even at the latter dosage, however, the total chlorine used will add up to only 400 pounds per week. Compared with a usage of 300 to 600 pounds per day when continuous low-dosage chlorination was practiced, this represents a very substantial saving.

As the chlorinator formerly used for continuous low-dosage chlorination has a maximum capacity of about 960 pounds per day or 40 pounds per hour, it is not suitable for the present intermittent, higher-dosage chlorination. Instead, the chlorine gas drawn from the one-ton cylinders passes through a manifold into a pressure regulator. At reduced pressure it enters a ⅝" plastic garden hose which, in turn, is carried through a two-inch "Uscolite" pipe leading through the inlet structure into the aqueduct line. The plastic hose extends for a short distance along the invert of the 72" pipe, permitting the gas to bubble upward into the flowing water. Although a larger chlorinator, which would permit application of chlorine solution rather than chlorine gas, would simplify control of chlorine dosage and, perhaps, promote more efficient use of the chlorine applied, even the present equipment is effectively maintaining full capacity in the San Diego Aqueduct at very moderate cost and simplicity of operation.

Acknowledgments

The author wishes to acknowledge the cooperation received from T. J. Cain, Division Foreman, San Diego Aqueduct, and from the District's softening and filtration plant laboratory staff.

The Metropolitan Water District of Southern California is operated under the direction of Robert B. Diemer, General Manager and Chief Engineer.

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(4) Jackson, L. A. and Mayhan, W. A. "Chlorination Maintains Supply Line Capacity," Water & Sewage Works 98: 248-252 (1951)

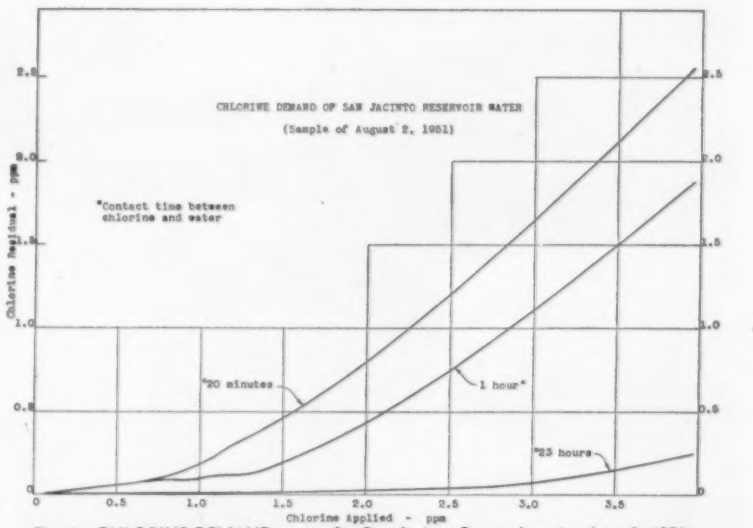
CHLORINE DEMAND OF SAN JACINTO RESERVOIR WATER
(Sample of August 2, 1951)
*Contact time between chlorine and water
Chlorine Residual - ppm
Chlorine Applied - ppm
*20 minutes
1 hour*
*23 hours

Fig. 6—CHLORINE DEMAND curves for San Jacinto Reservoir water Aug. 2, 1951

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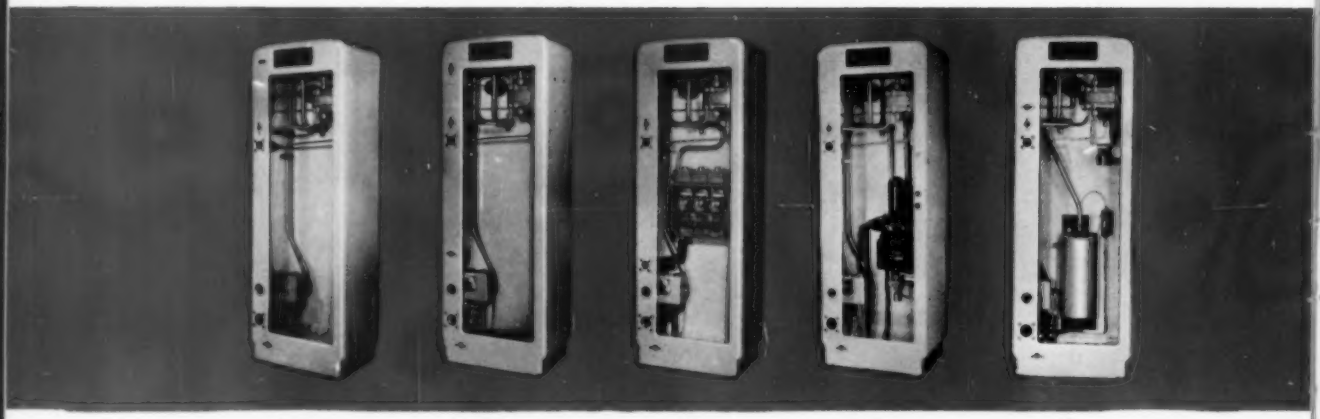


1 2 3 4 5

1 Manual operated 1050-A Chlorinator—Model C-1410

2 Automatic proportioning 1050-A Chlorinator—Model C-1420

3 Multiple rate 1050-A Chlorinator —Model C-1444

4 Remote set 1050-A Chlorinator—Model C-1455

5 Fluo 1050-A Chlorinator—Model F-1410
(For simultaneous fluoridation and chlorination)

Other Corrosion Resistant Chlorination Equipment

Fig. 1052-A High Capacity Chlorinator 8000 PPD max. (Also available with alarm system.)

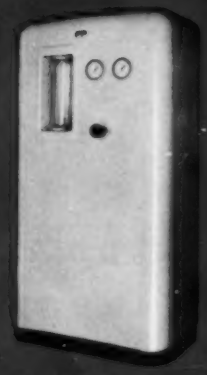


Fig. 1054 Portable Chlorinator

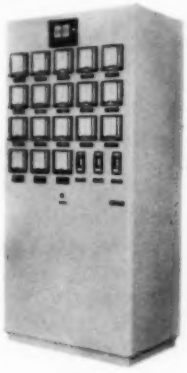
Fig. 1053-A Swimming Pool Chlorinator

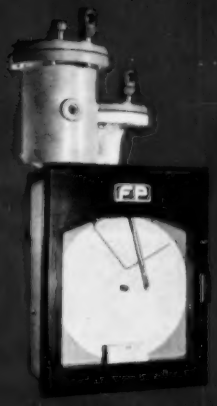
F&P Chlorine Flow Indicating Recorder

Water Purification

For measurement of filter water and wash water flow rates, F&P supplies a wide variety of flow meters and transmitters. The filter table console (below, left) contains all controls for operating a filter system.

The miniature instrument panel (below, right) houses indicators, recorders, totalizers, controllers and alarm systems for temperature, pressure, flow, liquid level and other variables.





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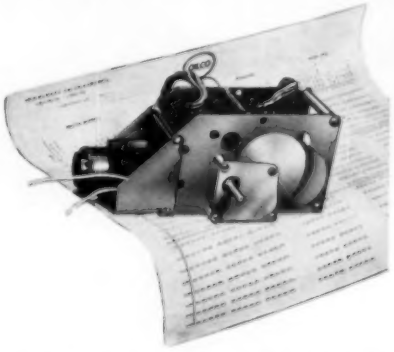
The F&P Centralized Data Logging System is a means of automatically translating pneumatic and electrical measurements to a digital (number) form for automatic control, computing or cost accounting. It can be used in an existing as well as a proposed water plant, and is the modern way of handling a number of continually changing operating measurements. Provisions can be made for positive supervisory control of the remote stations.

- Relieves operating supervisors of the burden of manually logging, collating and interpreting operating information.
- Increases efficiency through faster, more accurate reporting of works and operating conditions.
- Alarms abnormal conditions occurring at any time.
- Reduces confusion when information appears rapidly or from many points.
- Provides an automatic, permanent log independent of operating personnel.
- Stores data for subsequent use.

The F&P Automatic Logger presents data in typewritten form at hourly or other pre-set intervals.



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Iron Removal and Water Softening

By DANIEL J. SAUNDERS
Vice President, The Permutit Co., New York City

IRON and hardness are two of the most troublesome impurities in water supplies; iron because it stains everything with which it comes in contact and hardness because it wastes soap and forms scale. The tolerance for iron in municipal water supplies is usually stated as being 0.3 ppm., expressed as Fe. This concentration is only a very small fraction of the tolerance for hardness in municipal water supplies (i.e., usually 85 ppm. or 5 grains per gallon, expressed as $CaCO_3$).

If the iron content exceeds this 0.3 ppm., staining becomes a serious problem, for then the bathtub, washbowl and other porcelain fixtures no longer present a spotlessly white gleaming appearance but, instead, develop unsightly, rusty brown or even black stains which can usually be removed only by acid. (Parenthetically, it might be remarked that the common practice of having a bottle of muriatic acid at hand for the removal of such stains is not to be recommended especially where children are concerned and oxalic acid is even worse for it is exceedingly poisonous.)

Iron also stains glassware, tiled floors and walls and other materials. As for laundering in an iron bearing water, this presents such an extremely serious staining problem that laundering in a high iron content water is practically an impossibility. Iron also unites with tannic acid to form ink so tea made with an iron bearing water may, depending on the iron content, develop off colors from a grayish to a diluted black muddy appearance. Of course, as everyone who has used such a water knows, if lemon is taken with the tea, it does bleach out the color. Coffee, also, no matter what brand is used, becomes a rather muddy looking and unpalatable liquid. As for the plain drinking water if the iron content is 1 ppm. or over, an unpleasant metallic taste is very noticeable.

In the water supply distribution system, iron deposits tend to form, especially if the water has come in contact with air in a reservoir or storage tank. At times of heavy draft, these deposits are stirred up with the result that the water coming from household taps may temporarily become very muddy. Iron also favors the growth of various iron bacteria, popularly and collectively known as "iron crenothrix" and these growths have a tendency to break loose in clogging masses which frequently develop bad tastes and odors.

Methods of Iron Removal

In clear, deep well, iron bearing waters, the iron is present as soluble ferrous bicarbonate. Iron present in this form may be removed by (1) aeration, settling and filtration, (2) by cation exchangers operating either on the sodium or hydrogen cycle, or (3) if present in amounts of 1 ppm. or less, by manganese zeolite filters.

Iron in an organic or colloidal form may be present in some surface waters, some shallow well waters and an occasional deep well water. Usually such waters have an appreciable content of organic matter and a high color. Organic iron can not be removed successfully by the methods used for the removal of ferrous bicarbonate but can be removed by coagulation with alum, settling and filtration.

Aeration, Settling and Filtration

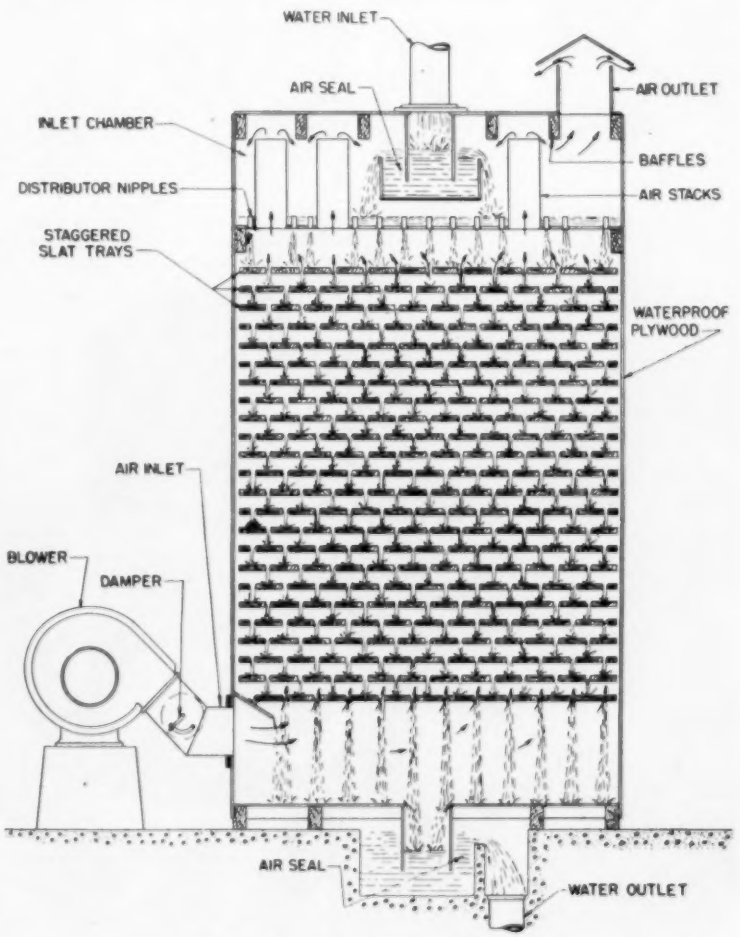
In the first process mentioned above for iron removal, the water is first aerated, which serves both to oxidize the iron and to reduce the content of free carbon dioxide. Certain other oxidizing agents, such as chlorine, may be used, instead of air, but aeration is the process almost universally employed.

Aeration may be carried out in one of several types of open aerators, such as the step aerator, spray aerator, slat aerator, coke aerator, or occasionally, in open basins by blowing air through the water. Also, aeration may be carried out in closed pressure type aerators or aerating filters. In such cases calcite filters may be employed to lower the CO_2 content. Aeration may also be done in a closed type degasifier rectangular in cross-section with one side removable for cleaning.

The oxidizing action of the air converts the soluble ferrous bicarbonate to the practically insoluble ferric hydroxide. With certain waters, this oxidizing action is so slow that it is advisable to speed it up by raising the pH value to approximately 8.2.

As an illustration of the increased speed of oxidation of a ferrous compound at higher pH values, ferrous sulphate, commonly known by the misnomer "copperas," may well be used. Every chemist is familiar with the fact that a solution of ferrous sulphate, which has a low pH value, is fairly stable and that, when exposed to the air, oxidation proceeds at a very slow rate. If such a solution is treated with caustic soda, thus greatly increasing the pH value, oxidation, when air is present, proceeds very rapidly, and insoluble ferric hydroxide is formed.

Similarly in waters of low pH value, containing ferrous bicarbonate, oxidation is slow although, of course, not so slow as



Section Through Rectangular Degasifier (Arrows indicate air flow)

with a solution of ferrous sulphate, which has a very much lower pH value. Therefore, aeration, by reducing the free carbon dioxide content, builds up the pH value and increases the speed of the oxidation. If, in addition, the pH value is increased by an alkali such as hydrated lime or caustic soda, the speed of the oxidation reaction is greatly increased.

The insoluble ferric hydrate produced by this process, may then be removed from the aerated water either by settling or by filtration, or more commonly, by settling followed by filtration. In the latter case, the settling is usually for a comparatively short period, some 15 to 30 minutes.

Filtration is accomplished by the use of sand or anthrafilt filters of either the gravity or pressure type. These are standard filters and as they are operated in the usual manner, no detailed description is necessary. In addition to the usual backwash, surface washers are frequently employed.

Cation Exchange

The removal of ferrous bicarbonate by cation exchange may be accomplished simultaneously with the removal of hardness by cation exchangers operating on either the sodium cycle or the hydrogen cycle. In municipal practice, the sodium cation exchanger process is the one that is almost exclusively used. The cation exchanger may be a green-sand base zeolite, or a carbonaceous or resin type.

When a clear, deep well water is to be softened and also freed from iron, the zeolite water softener may offer the simplest solution to the problem. With most of these waters, the removal is so complete that the iron content of the effluent will usually average 0.1 ppm. or less. In fact, in a few cases, zeolite water softeners have been installed primarily for iron removal, the water softening action being an incidental benefit.

On regeneration with salt, the iron, which has been taken up by the zeolite on the softening run, is liberated as ferrous chloride. This, together with the calcium and magnesium chlorides, is then thoroughly washed to the drain before returning the softener unit to service.

This process will answer for all normal water supplies; for waters of abnormally high iron content aeration, settling and filtration frequently precede zeolite water softeners.

Since the zeolite (or sodium cation exchanger process) yields a water of "zero" hardness, it is customary to by-pass enough hard water to give a mixed effluent with a hardness of about 5 grains per gallon. If the iron content of the raw water is too high to yield a mixed effluent with the desired iron tolerance, the by-pass water should be reendered iron free by separate treatment.

Manganese Zeolite Process

When the iron content is relatively low—1 ppm. or less—and softening is not required, the iron may be removed by means of manganese zeolite filters. The manganese zeolite is a special zeolite manufactured by converting a sodium zeolite to a manganese zeolite by treating it first with manganous chloride and then with potassium permanganate.

In order to remove iron by this process, the water is simply filtered through a bed of the manganese zeolite. This serves both to oxidize the iron to an insoluble form and to remove this product by the filtering action of the bed. These accumulations are removed by periodic backwashings and the oxidizing action is restored by occasional regenerations with potassium permanganate. In this process, only the iron is removed from the water as the manganese zeolite exerts no softening effect.

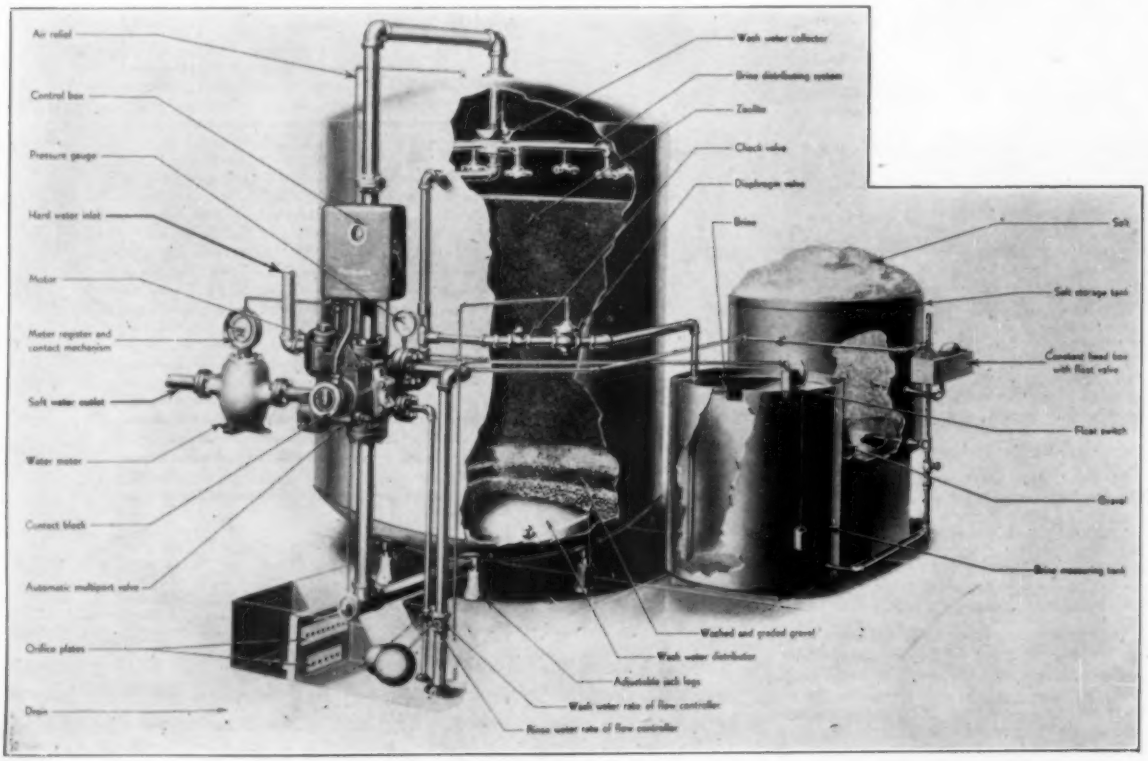
Cold Lime Soda Process

In the cold lime soda (or combination lime zeolite process), ferrous bicarbonate is easily removed with the hardness precipitates by introducing sufficient air into the water to oxidize the iron. If the carbon dioxide content of the raw water is rather low, all that is required is to drop the water, over a couple of steps or baffles, through an air space as it enters the treating tanks. If the water contains a relatively high content of carbon dioxide, then marked economies in the lime dosage may be effected by first passing the raw water through an aerator which may be mounted over the treating tank.

Organic or Colloidal Iron Removal

As previously stated, organic or colloidal iron is not satisfactorily removed by the foregoing processes. Instead it is necessary to coagulate, settle and filter the water. This is not always as simple as it sounds and it usually is necessary to run a series of jar tests to find the optimum conditions, that is, the dosages of coagulant and the pH requirements to secure a good coagulation and the formation of a satisfactory floc. The coagulant which is most widely employed is aluminum sulfate—filter alum—but chlorinated copperas and ferric sulfate are also used.

Chlorination is sometimes of value in removing organic iron but in many cases it seems to have little or no effect. With waters of low mineral content, the use of clay or activated carbon is often of value in aiding floc formation and color removal.



Cut-away of Zeolite Water Softener

Manganese Removal

Manganese, like iron, is an exceedingly troublesome impurity in water but fortunately is much rarer in occurrence. Like iron it may occur as the soluble bicarbonate or in colloidal or organic form. Also its methods of removal are similar, manganous bicarbonate being removed by (1) aeration, settling and filtration, (2) by cation exchangers operating either on the sodium or hydrogen cycle, or (3) by manganese zeolite filters. In removing it by aeration, settling and filtration, however, it is necessary to have a higher pH for its oxidation than is required for iron. In the organic or colloidal form, the method of removal is the same as with iron, that is, by coagulation, settling and filtration.

Municipal Water Softening

Hard waters, as everyone who has used them can well testify, are expensive nuisances. They waste tons of soaps; decrease the life of washable garments; making bathing, shampooing and shaving thoroughly unenjoyable; scale water heaters, boilers, hot water piping and cooking utensils; and increase costs for fuel, labor, repairs and replacements. While these trials and tribulations are recognized by all users, too few realize that it actually costs much less to soften a hard water than to continue using it. Surveys however have proven that, on the average, the costs for the materials used in softening a municipal water supply are only about one-third the cost of the soap wastage incurred in using the hard water.

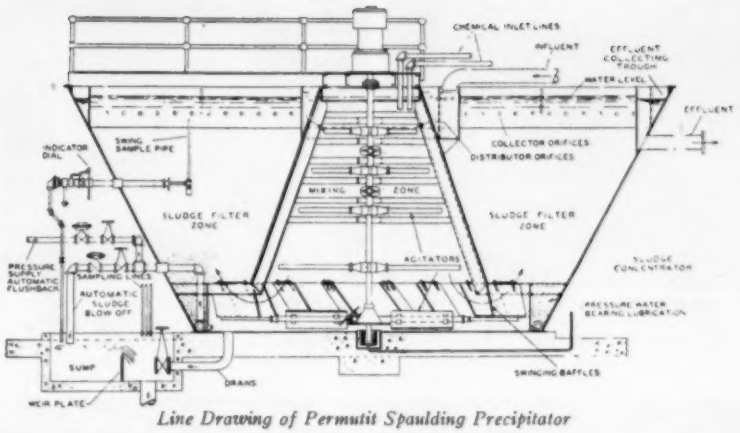
There are three processes which are used in softening municipal water supplies. These are:

1. The zeolite (or sodium cation exchanger) process
2. The cold lime soda process
3. The combination lime-zeolite process

Zeolite (or Sodium Cation Exchanger)

In the zeolite (or sodium cation exchanger) process, the hard water is softened by merely flowing it through a bed composed of a granular sodium zeolite or an organic sodium cation exchanger. This removal of the hardness is so complete that the softened water is usually termed "zero water" meaning a water that is practically zero in hardness. After a definite amount of hardness has been abstracted, the bed is treated with a predetermined amount of common salt brine, which removes the hardness from the bed and restores it to its original sodium condition.

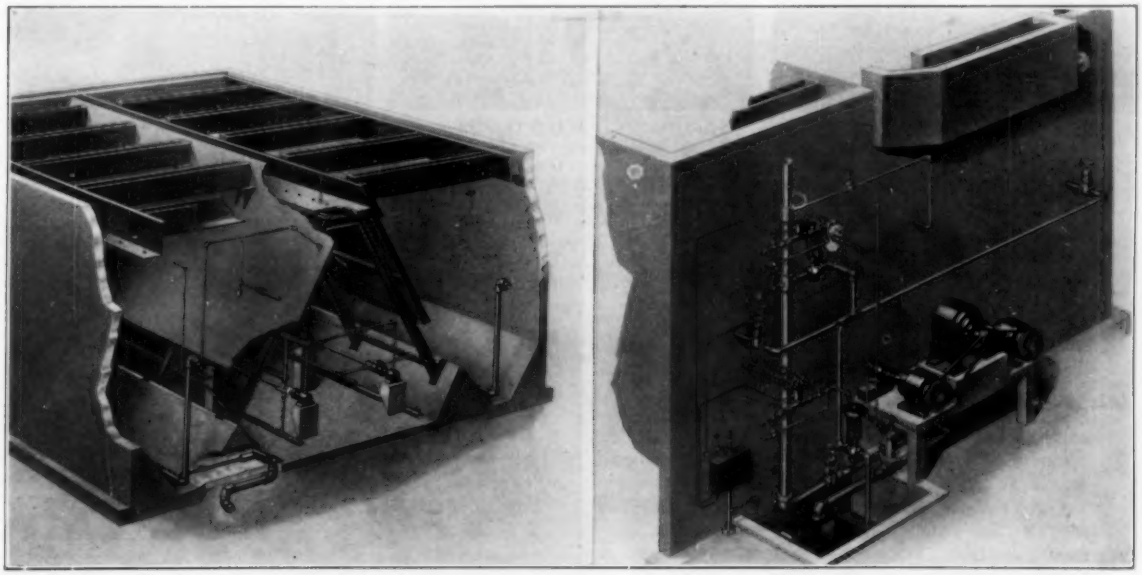
This restoration process is known as "regeneration" and consists of three steps: backwashing, salting and rinsing. The backwashing serves to loosen, cleanse and hydraulically regrade the bed. The salting serves to remove the hardness and simultaneously to restore the bed to its original sodium state. The rinsing serves to remove the excess salt and soluble by-products—calcium and manganesium chlorides—and wash them down the drain. These cycles of softening and regeneration may be repeated indefinitely as the wear and tear on the bed is very slight—usually under 3 per cent per year. Therefore only a slight addition of new material is required annually to keep the bed performing at its full rated capacity.



Line Drawing of Permutit Spaulding Precipitator

The softening plant may consist of a single softener unit or batteries of two or more units. In the latter case the units are usually of such a size that, when one unit is being regenerated, the other unit or units carry the full load. The softener units used in municipal practice may be either of the pressure type or the gravity type. In the pressure type, the bed is enclosed in a steel shell; in the gravity type, the bed is enclosed in a rectangular concrete shell. In both types, the bed is supported by several layers of graded gravel overlying an underdrain system. This serves to collect and pass the softened water to the service lines during the softening run; to distribute the backwash water during the backwashing operation; and to collect and pass to the drain the waste brine and rinse water during the salting and rinsing operations.

Zeolite (or sodium cation exchanger) water softeners are available in fully automatic, semi-automatic or manually operated designs. In the fully automatic pres-



Cut-away View of Horizontal "Precipitator"

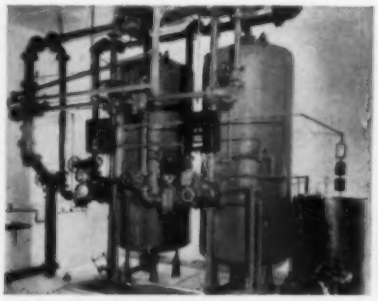
Left—Interior; Right—Front Wall

TURBIDITY gets cut from 1500 to less than 5 ppm in this Precipitator. Mt. Carmel, Ill. Cons. Eng.: *Warren & Van Praag, Inc.*

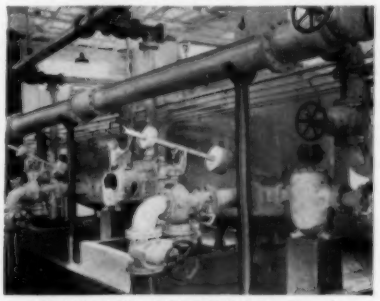
SEA WATER saves $32,980 per year over salt for regenerating Softeners. Hollywood, Fla. Cons. Eng.: *Reynolds, Smith & Hills.*

30 PPM IRON gets cut to 0.14 ppm in Aerator and Precipitator . . . even before filtration! Fairless Hills, Pa. Cons. Eng.: *H. H. Le Van, Jr.*

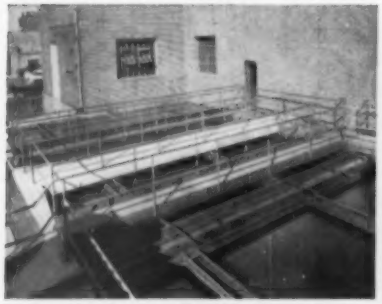
HARDNESS TESTER starts regeneration of softeners automatically, saves manpower. E. Aurora, N. Y. Village Eng.: *E. J. Maurer.*



269 PPM HARDNESS is removed by these automatic Softeners. Aerator and Filters cut iron. Martinsville, Ill. Supt.: *O. Wiser.*



AUTOMATIC CONTROLS backwash, regenerate, rinse and return Softeners to service. New Smyrna Beach, Fla. Cons. Eng.: *Russell & Axon.*



OLD SETTLING BASINS house these modern Precipitators that boost capacity. North Kansas City, Mo. Cons. Eng.: *C. A. Haskins.*

SOFTENER CAPACITY TRIPLED and $7,000 yearly saved on salt by change to Permutit Q resin. Normal, Ill. Cons. Eng.: *Farnsworth & Conley.*

TRIPLE TROUBLE! 275 ppm hardness, 200 ppm alkalinity, 3 ppm iron are reduced by this Precipitator. Staples, Minn. Supt.: *E. H. Klang.*

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sure type softener, a motor operated valve is usually mounted on the front of the softener unit. In the gravity type softener, a motor operated pilot valve is used to regulate the hydraulically operated gate valves on the softener unit.

In either case, the principles of operation are the same. A water meter on the soft water outlet line is equipped with an electric contact head and an automatic resetting device. At the end of the softening run, a contact is made establishing an electric current which rotates the valve to the wash position. The length of the backwash period is governed by an electric time switch.

At the end of the backwash period, a current is again established which rotates the valve to the brine position. In this position, a predetermined volume of saturated salt brine is admitted to the softener, this volume being governed by an electric float switch. After the brine has been admitted the valve is rotated to the rinse position. The rinsing period is governed by an electric time switch and, at the end of this period, the valve is rotated to the soften position, which again places the softener unit in operation. In the meantime the resetting device on the meter has automatically reset it for the next softening run.

Semi-automatic operation is used principally on waters which may suddenly vary in composition. The semi-automatic units are similar to the fully automatic in operation with the single exception that the regeneration and return to service operations are initiated by the operator instead of by the meter. Manual operation is performed by the operator opening and closing the proper valves in sequence, timing the backwashing and rinsing operations and measuring the drawdown during the salting operation. The valves used may be either of the conventional type or the hydraulic type, the latter being operated from a control table.

In municipal practice, effluents having a hardness of 4 or 5 grains per gallon are usually desired. With the zeolite (or sodium cation exchanger) water softener, such effluents are obtained by softening a portion of the water to "zero" and then mixing with it whatever proportion of hard water is required to reach the desired quality of effluent. If the raw water contains appreciable amounts of iron, it is the usual practice to treat the raw water and remove its iron content before mixing it with the softener effluent. (See Iron Removal Section above.)

Cold Lime Soda Process

In the cold lime soda process, the hard water is treated with lime or lime and soda ash, added in such proportions and amounts as to precipitate the bulk of the hardness in the forms of calcium carbonate and magnesium hydroxide. The function of the lime is to remove free carbon dioxide; to change the calcium bicarbonate to the insoluble carbonate and when magnesium hardness reduction is required, to precipitate it as magnesium hydroxide. The function of the soda ash is to convert the chlorides or sulfates of lime and magnesia to the carbonates.

In waters which contain little or no sulfate (or non-carbonate) hardness, treatment with lime alone will be sufficient to reduce the hardness to the required tolerance. On the other hand if the non-carbonate hardness exceeds some 3 grains per gallon, the use of soda ash as well as lime is required to produce a 5 grain per gallon effluent. In either case, the addition of a small amount of a coagulant—usually about 20 ppm. of aluminum sulfate—is desirable in order to form an easily settled floc.

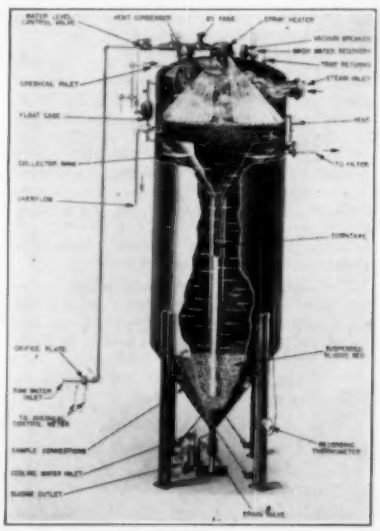
Sludge Blanket Softeners

In the older or so-called "conventional" cold lime soda water softeners, treatment and settling was effected in large settling tanks or basins and the effluent was usually recarbonated before passing through the filters in order to prevent "growth" of the filter granules and "after deposits" in the distribution system. In the newer, sludge-blanket type of equipment, the treated water, by being brought in intimate contact with previously formed precipitates, is brought into chemical balance so that recarbonation is unnecessary unless a lowering of the pH value is required.

For the purpose of explaining this system, the "Permutit Spaulding Precipitator" will be described. The "Precipitator" is available in two basic types, the vertical and the horizontal and in sizes ranging from 10 mgd. per unit down to small units for carbonated beverage plants and other such uses, with capacities of only a few thousand gallons per day. Also it is possible to convert many of the older settling basins and tanks to the "Precipitator" type by remodeling their interiors and thus increasing their efficiencies, lowering their lime requirements and increasing their capacities.

The vertical "Precipitator" may be described as a cone, cut in half, the smaller portion, with the largest diameter downwardly disposed, being placed in the center of the larger portion, with the largest diameter upwardly disposed and with, of course, a space between the lower rim of the downcomer and the bottom of the tank. This downcomer is equipped with a centrally disposed, vertical agitator. The horizontal "Precipitator" differs from the vertical type in that the outer chamber is a rectangular concrete tank; that the inner chamber or downcomer is formed by sloping partitions and that two horizontal agitators are employed in the inner chamber, these being driven by a motor placed in a drive pit at one end of the Precipitator.

The principles of operation are the same in both types and may briefly be described as follows: The raw water and the chemicals enter at the top of the inner chamber and pass downwardly through it, the agitator serving to thoroughly mix the chemicals with the water and to keep the precipitates, formed by the reactions, in suspension. Emerging at the bottom of the inner chamber, the treated water flows upwardly through a suspended blanket of previously formed sludge. As the cross-sectional area of this outer chamber increases from bottom to top, the vertical velocity of the rising water constantly decreases until a level is reached beyond which it cannot lift the precipitates. In practice, there is a clear line of demarcation between the top of the sludge blanket and the clear effluent rising above it to the outlets.



Hot Process Softener—Sludge Blanket Design

The intimate contact thus obtained between the precipitates and the water results in a complete utilization of the added lime; elimination of super-saturation and after-precipitates; and, due to the filtering action of the sludge blanket, the production of clearer effluents and longer filter runs.

The depth of the sludge blanket is kept between specified limits by bleeding off sludge, through sludge concentrators, at approximately the same rate at which new sludge is formed. These sludge concentrators are relatively small compartments in the bottom of the outer chamber through which there is no upward flow of water and in which, therefore, the requisite part of the sludge settles and concentrates to about 10 per cent solids.

In municipal practice, the effluent from the "Precipitator" is filtered before passing to the clear well. The filters used are usually of the gravity type and therefore need no detailed description. In addition to their use in the cold lime soda water softening process, "Precipitators" may be used for the coagulation of turbid or colored waters.

Combination Lime Zeolite Process

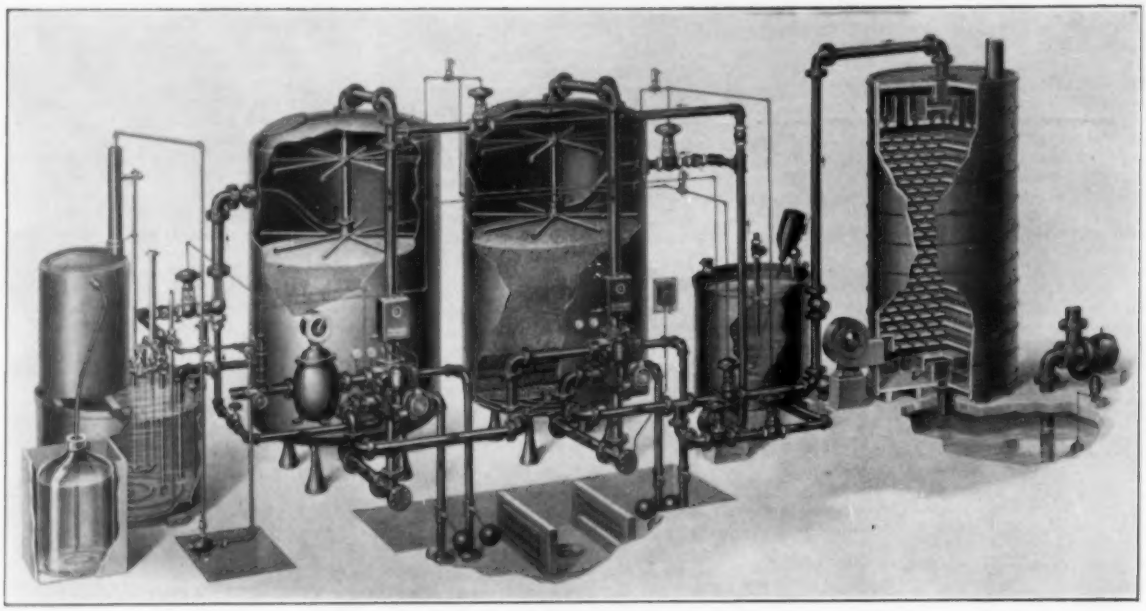
In the combination lime zeolite process, the water is first treated with lime to reduce the bicarbonate hardness. The filtered effluent is then passed through a zeolite (sodium cation exchanger) water softener to remove the noncarbonate hardness and residual carbonate hardness. With waters containing appreciable amounts of noncarbonate hardness, this process shows very economical operating costs as the cheapest method of removing bicarbonate hardness is with lime and the cheapest method of removing noncarbonate hardness is with zeolite.

Further advantages with this process are that it reduces the alkalinity and total solids content and that, where iron removal is concerned, the iron can be removed in the first stage of the process by introducing enough air to oxidize the iron to the ferric state. In using this process for municipal water softening, the usual 5 gpg. effluent may be obtained by mixing the requisite portion of the filtered lime treated water with the zeolite effluent.

The system used consists of a cold lime softener plus filters plus zeolite water softeners. If the pH value of the lime treated water is too high, a slight recarbonation will serve to reduce it. If the raw water is an iron or manganese bearing water, or, if the free carbon dioxide content is high, an aerator is employed ahead of the cold lime softener. This may consist of a coke tray or wood slat tray aerator; or, if only a slight aeration is needed, running the water over a few steps or baffles before it enters the cold lime softener will be sufficient; or, the air may be introduced by an air grid and compressor in a compartment ahead of the lime treatment.

Demineralization Process

While the hydrogen cation exchanger process, the ion exchange demineralizing process, find other uses than in the treat-



Automatic Demineralizing Plant with Degasifier

ment of municipal water supplies, a brief description of them may be of interest. In the hydrogen cation exchanger process, the cation exchangers used are of the organic or non-siliceous types. These organic cation exchangers may, when regenerated with salt, be used in the same manner as the siliceous zeolites. Their most interesting use, however, is on the hydrogen cycle.

On the hydrogen cycle, the cation exchanger is regenerated with acid, usually sulfuric acid. The hydrogen thus introduced into the cation erchanger will exchange hydrogen for calcium, magnesium and sodium ions.

If a water containing nothing but the bicarbonates of these metals is passed through a hydrogen cation exchanger, the calcium, magnesium and sodium will be completely removed and nothing but free carbon dioxide will be left in the effluent. As the carbon dioxide is easily removed by aeration, such an aerated effluent would be practically the same as distilled water in composition.

However, if sulfates and chlorides are also present, these would appear in the effluent as the corresponding acids. These may be neutralized by the addition of soda ash or by mixing with the requisite quantity of water softened on the sodium cycle.

On the other hand, if complete removal of the sulfates and chlorides is required, then the effluent from the hydrogen cation exchanger is passed through an anion exchanger which completely removes the sulfuric and hydrochloric acids formed by the hydrogen cation exchanger. The carbon dioxide is then removed by aeration resulting in an effluent equivalent to a distilled water. As the cost of demineralization is only a very small fraction of the cost of distillation, this process is now coming into very extensive use wherever a water of such high quality is required.

Hot Lime Soda Process

The hot lime soda process, too, may be of interest, although not used for municipal softening. It is confined almost exclusively to the softening of boiler feed waters as the process is carried out at the boiling point. The softener consists of a tall enclosed steel tank designed usually to withstand a pressure of about 10 psi. In the top of the softener is a spray heater, which heats and deareates the water to less than 0.3 ml. per liter of dissolved oxygen.

The lime and soda ash are fed to the hot water in the top of the softener where it reacts with the hardness producing a sludge. In the newer sludge blanket type design, the water flows through a downcomer in the center of the softener and then rises through a blanket of this suspended sludge. In the older types, the flow was downward to a short distance above the bottom where the treated water was drawn off through a cylindrical uptake while the sludge settled to the bottom.

The sludge blanket type has rapidly come into popular favor particularly where the silica content, as well as the hardness, requires reduction or removal and it is built in a number of designs for handling makeup alone or both makeup and various amounts of condensate and for either a deaeration to 0.3 ml. per liter of dissolved oxygen or complete deaeration to less than 0.005 ml. per liter. In the latter case, the complete deaeration is effected by a clever use of the steam required for the primary heater; this steam being blown through the hot, softened and partially deaerated water in a deaerator compartment before being used in the primary heater.

The hot process softener will reduce the hardness to below 1.5 gpg. (25 ppm.) by the use of lime and soda ash alone and to as little as 1 or 2 ppm. when phosphate also is used. Also, by the use of dolomitic lime or activated magnesia, the silica content may economically be reduced to practically any desired figure.

The effluent from the hot process softener is filtered through pressure filters using a non-siliceous filter medium such as "Anthrafilt." These filters are periodically backwashed with hot softened water from the settling tank by means of a special backwash pump and the backwash water is returned to the top of the settling tank, thus recovering it. Since the process is carried out at temperatures around the boiling point, the softener tank and filters are usually lagged with insulating material to prevent heat losses. As previously stated, this process is almost exclusively limited to softening boiler feed waters, the few exceptions being where a very hot, softened process water is required.

Compressed Air in Water Works

by EDMOND C. POWERS

Educational Director, Compressed Air and Gas Institute, Cleveland, Ohio

THE APPLICATIONS of compressed air in water pumping stations and treatment plants until recently have been limited. Although not completely incongruous in the average water works, compressors nevertheless have occupied a relatively minor position among the pumping stations[1] components.

With the exception of maintenance functions and those water works using air lift pumps, the need for compressed air was confined to pipe testing, caulking operations, and minor control systems that required one or two small capacity, light duty compressors of perhaps 0.5-horsepower each.

Now, however, the ever-increasing recognition of compressed air as a safe, simple, and dependable mode of power has caused its application to spread throughout the entire pumping station, enveloping control devices of all types, aerating systems, soot blowing, and a host of other associated water works activities. A few of these applications are briefly reviewed here to show what compressed air can do better and cheaper for the water works operator.

Air Lift Pumping

If air lift pumping is not the oldest compressed air application in the water works, it certainly must be close to the oldest such application. Successfully used for many years in a number of stations, this unit is by no means obsolete. It still finds wide acceptance in deepwell areas where long-shafted vertical turbine and submersible wet pit pumps are impractical or uneconomical.

Its chief advantages are that it has no submerged wearing parts to be affected by abrasives suspended in the water, and crooked well shafts do not materially affect its operation. Water contamination by the pumping medium is practically nil, thereby reducing the filtration and purification requirements to a slight degree.

Furthermore, because the power source is centralized and may consist of a single compressor and motor to handle a group of wells, installation costs are lower. On the other hand, to provide an individual mechanical pump and motor for each well of a field sometimes results in numerous substations a considerable distance from each other. With air lift pumps and a centralized power source, accessibility and maintenance problems are simplified.

Aeration Uses

Where aeration figures prominently in conditioning the water, compressed air offers real possibilities.

Two of the more important considerations in efficient aeration are (a) the amount of air-water surface, and (b) the duration of the air-water contact time. Since air at a given pressure can be made to pass through smaller pipe openings than water at the same pressure, the air can be broken up into countless small bubbles that will present a maximum air-water surface ratio. Of additional importance is the fact that an air bubble will require a longer time to reach the liquid surface than will a sprayed water droplet to fall back to the water. The contact time between the water and air, therefore, is increased substantially, providing better aeration. The obvious advantages of control pressure variation in such a system immediately open up new possibilities in aeration control.

It is conceded that the greater the air pressure, the greater will be the volume of air flow. But greater air flow also means increased aeration taking place. If, then, instruments could be used to periodically measure the condition of the water, automatic control of aeration could be achieved. On dictation by the instrument measuring the condition of the water, the volume of air for aeration could be varied to meet the immediate requirements of the water conditioning system.

In many instances severely cold weather will influence spray-type aeration systems to such an extent that the use of compressed air is an absolute necessity if aeration is to retain its efficiency. Seasonal and perhaps daily changes in aeration requirements are easily handled with compressed air.

$$T = \frac{V(P_1 - P_2)}{C P_0}$$

- T = Time receiver will supply air from upper to lower pressure limits, in minutes.
- V = Volume of receiver, in cubic feet.
- P_0 = Atmospheric pressure, in pounds per square inch absolute.
- P_1 = Maximum tank pressure (compressor discharge pressure), in pounds per square inch absolute.
- P_2 = Minimum tank pressure (pressure required to operate tool), in pounds per square inch absolute.
- C = Air required (from study of load cycle), in cubic feet per minute.

Fig. 1—PROTECTION provided by compressed air system in event of power outage

Filter Cleaning

Filter beds, too, can be reactivated faster by means of air under pressure. Speed of reactivation is a vital factor in the warm months when water consumption is at its peak and the shutdown time of a filter bed for cleaning must be at a minimum.

Low-pressure air for agitation of the sand will reduce backwash time considerably. The same air system that is used for maintenance can be used here also. It only becomes necessary to install pressure regulating valves immediately before the air distribution pipes in the filter beds. A reduction of the air pressure to about

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HEAVY PNEUMATRACTOR AND BACKHOE

The Schramm Backhoe, mounted on Heavy Pneumatractor, is the most powerful backhoe made for a wheel tractor. Because of its hydraulic action and control by two levers, it digs much faster than the more expensive cable-operated backhoes with multi-lever control. It is the only tractor type backhoe powerful enough to operate as a shovel. With buckets available from 12 to 36 inch widths, you can dig to a depth of nine feet six inches. Tampers and shovel buckets can also be installed on the backhoe, making it the most versatile tool of its kind. Full details in Catalog 5540.

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The Schramm Front End Loader, mounted on Heavy Pneumatractor in combination with the Schramm Backhoe, makes the Pneumatractor a complete digging and materials-handling machine. It will do an endless variety of jobs—loading, digging, bulldozing, grading, tamping, lifting, sweeping. Standard attachments are furnished by Schramm, including a portable scaffold which lifts to 13 feet above ground. The Schramm Front End Loader has hydraulic action to the bucket, hydraulic action to raise and lower the loader frame, and hydraulic action to the blade, boom, and other attachments. Complete description in Catalog 5540.

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10 pounds per square inch is adequate in most plants.

With a cleaning pressure of 10 pounds per square inch, and a plant air system with a pressure of 100 pounds per square inch, only a small air receiver is required to store sufficient air for a cleaning cycle. For instance, a 90 cubic foot receiver holding air at 100 pounds per square inch would supply approximately 420 cubic feet of air at 10 pounds per square inch.

This ability of the compressed air system to store up power by means of air receivers is one of its most outstanding features. Extra large storage tanks can provide air to operate controls, valves, and other vital components for minutes after a power failure has shut down the electric system. The equation in Fig. 1 can be used to check the plant system to see how well it protects against emergencies.

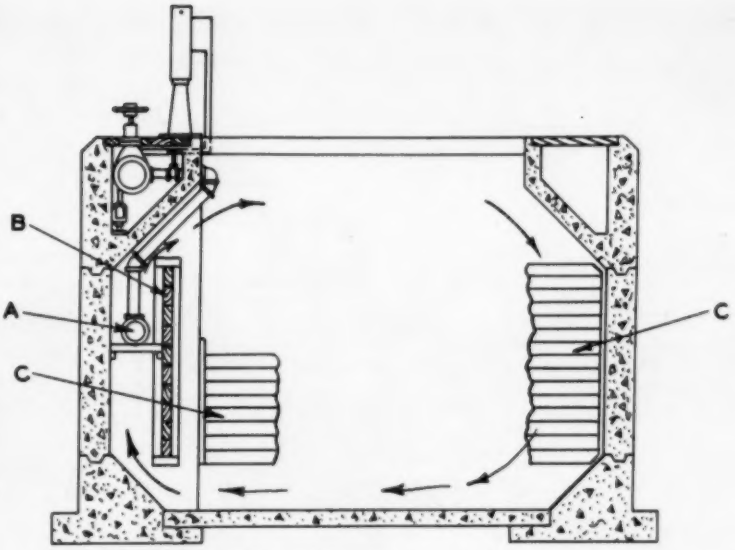

Fig. 2—AERATOR-FLOCCULATOR operated by compressed air

Flocculation

Most flocculation processes require rapid mixing at the beginning, with the mixing diminishing as the process approaches the end of the cycle. In many instances the speed of the process must be altered to suit a special treatment, a condition that is particularly well handled by compressed air.

Consider an aerator-flocculator similar to that shown in Fig. 2. It consists of a compressed air header, A, which emits a controlled air stream. The air causes the water and flocculation material to swirl in the tank, with baffles B and C directing the movement of the water to assure correct mixing. Aeration and flocculation take place simultaneously, and can be varied easily for current water conditions by either automatic or manual means. With automatic operation, the personal equation of error is reduced, if not eliminated entirely, offering a foolproof system.

Reduced Contamination

The complete absence of moving parts in this, as well as the aeration systems, is particularly attractive from the standpoint of maintenance. Furthermore, contamination of the water is practically non-existent. Aftercooling and separating devices remove entrained impurities from the air stream prior to its reaching the distribution point. Filters are available that will go further in cleansing the air by removing fine dust particles, and even undesirable odors.

Completely oil free air, through the use of carbon ring, non-lubricated compressors, will further preclude the possibility of water contamination and clogging of delicate control instruments by lubricating oil. The cast-iron piston rings are replaced by segmental carbon rings sliding on a honed cylinder bore that requires no lubricant. Piston rod packing is also made up of carbon rings (sometimes hemp), and positive protection can be had by inserting an extra long housing between the cylinder and the compressor frame, so that no part of the rod which enters the crankcase also enters the cylinder. A collar on the rod prevents oil from creeping along it into the cylinder packing box and bore.

Chemical Handling

The special construction mentioned in the preceding paragraph is sometimes necessary on compressors engaged in chemical transmission, particularly that type known as tank car unloading. Here the compressed air is piped to the top of the tank car, forcing the liquid inside to leave the car through another pipe extending to the bottom of the tank. This latter pipe is connected to the storage tank in the area of use, so that the liquid chemical is rapidly moved from place

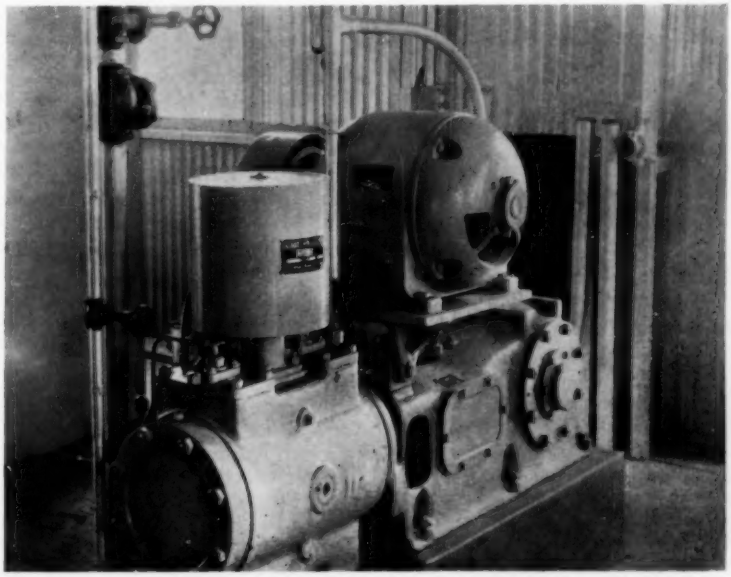

Fig. 3—NON-LUBRICATED instrument air compressor of heavy-duty type capable of delivering 1,245 cubic feet per minute of 60 psi discharge.

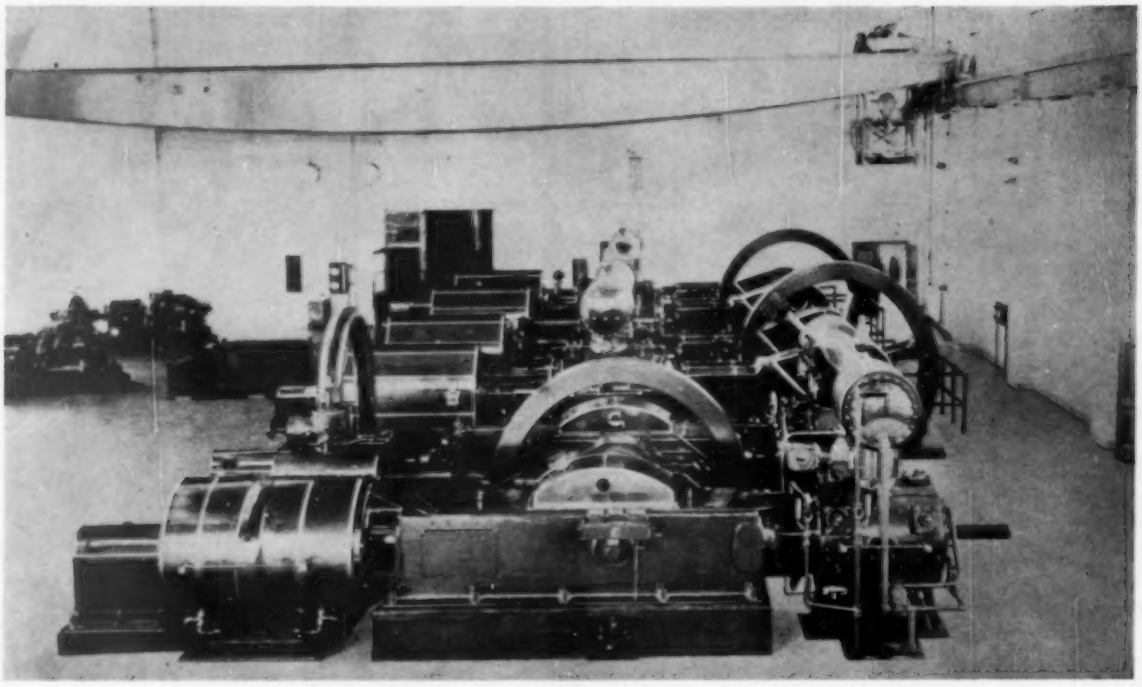

Fig. 4—STEAM-DRIVEN compressors on air lift pump service in a large southern city

to place without the use of expensive special pumps that are used only periodically.

Dry chemicals are skillfully and easily moved by canvas conveyor belts that are fluffed by compressed air.

Vacuum pumps also will handle chemicals with neatness and dispatch by creating a pressure differential between the chemical storage tank and the atmosphere. A hose attached to the tank sucks the chemical in, much in the manner of a giant-sized vacuum cleaner.

Chemical transfer by air pressure eliminates the human element that sometimes results in loose handling and slop-over, both of which are reflected in the overall cost of the chemical. Workers are also protected from the dangers of handling corrosive chemical agents, greatly enhancing plant safety practices, and compressed air never becomes tired.

Maintenance Tools

Maintenance, of course, has always been an important function of compressed air. In the use of maintenance tools, air is unequalled as a source of power. Lightweight construction, high speed operation, and freedom from electric shocks are important arguments in favor of compressed air.

Portable compressors constitute one of the greatest assets of the maintenance sections. Pavement breaking, rock drilling, and earth tamping are all facilitated by compressed air equipment at the site.

Pumping out water-filled excavations can be accomplished by portable units operating miniature air lift pumps. Maintenance of the equipment is thus kept to a minimum; large stones, gravel and broken concrete are easily handled without fear of blade or piston breakage as would be the case with centrifugal or reciprocating liquid pumps.

Miscellaneous Uses

Compressed air does not stop with those functions directly concerned with pumping or treating water.

Boiler feed control instrumentation, soot blowing, boiler tube cleaning, and ash removal all can be handled automatically with compressed air.

Carbonaceous material adhering to boiler tubes must be blown off if the steam generator is to perform at peak efficiency. Compressed air, although having a somewhat greater initial cost in some cases, permits the use of low temperature, uninsulated piping and does away with the waste of high-pressure steam. Compressed air soot blowing also has a lower operating cost than a steam cycle.

Control and instrumentation also belong among the water works components serviced by compressed air.

Exceptional sensitivity, dependability, and low cost have all contributed heavily to the use of air controlled and operated chlorinators, traveling screens, chemical mixers, boiler feed pumps, water pump discharge valves, and similar station equipment. By means of Bourdon tubes, bellows, and diaphragm needle valves, all air activated, pressure changes within a system are quickly picked up and magnified, so that sensitivity of less than one per cent is easily achieved.

A Versatile Tool

From street pavers to such simple functions as blowing the dust from a workman's bench, compressed air occupies a prominent position in the water works field. But with all its inherent ruggedness and built-in long life, the compressor must rely on the consideration of the operator and engineer to offer its maximum efficiency.

Intake filters to keep the cylinders free from abrasive dust; the proper amount and temperature of jacket cooling water (on water cooled units) to prevent overheating and moisture condensation; aftercoolers, separators, and traps to insure clean dry air being supplied to the end point; air receivers for storage purposes and pulsation damping; and a strict maintenance schedule that will assure periodic inspection of the compressor, inside and out, are all vital to the proper operation of the compressor.

Fluoridation by Automatic Control

Treatment can be accurately recorded and controlled by means of an electrical conductivity instrument

by KENNETH F. KNOWLTON

Superintendent-Chemist, Salem and Beverly Water Supply Board, North Beverely, Mass.

A METHOD has been developed for continuously monitoring the fluoride content of the water treated in the North Beverly, Mass. filtration plant of the Salem and Beverly Water Supply Board. The author described the new development in a paper presented before the New England Water Works Assn. in 1953.

Additional data concerning the monitoring of fluoride has been accumulated and, more recently, the equipment has been adapted to actual control of the fluoride dose. The opening paragraphs of the author's earlier paper[1] describes the equipment and principles employed.

Electrical Conductivity Method

"Adaptation of the use of electrical conductivity is the basis of the method of fluoride recording which was used in this study. We all know when salt is added to water, an electric current will pass through the water more easily than it would without the salt. Any material which ionizes in water will show this same characteristic to some extent, and instruments have long since been developed to measure minute changes in the electrical conductivity of water. Procedures and definitions have been adopted for discussing these phenomena.

"Electrical conductivity is the reciprocal of electrical resistance, or one divided by resistance, expressed in ohms (1/ohms).

"The word 'mhos' (ohms backwards) is used to express units of conductivity. Specific conductivity is the conductivity at a given temperature of the material under test, as measured by two platinum plates, each one square centimeter in area and placed one centimeter apart. Since the conductivity is usually low (resistance high), we normally speak of micromhos, or units of a millionth of a mho.

"In the measurement of fluoride, arrangements are made to determine the specific conductivity of the water before fluoride addition and again after the addition of the chemicals. At Salem-Beverly the base conductivity of the water is in the order of 145 micromhos at 25°C.

"Since both sodium fluoride and sodium silico fluoride ionize in water, there is a change in the conductivity of the water when they are added. If measurements are delicate enough and all other factors, except the added fluoride, can be eliminated, we have a good method for adaptation to continuous analysis for the amount of the material which is added to the water."

Two Standard Cells Used

The heart of this system lies in the conductivity cells used to measure the electrical conductivity of the water before the fluoride is added and after the fluoride is added.

Fig. 1 is a photograph of a standard industrial type of carbon cell which is being used. These cells are made so that they may be inserted through the side of the pipeline and operate against 150 psi pressure, or they may be inserted directly into tanks or other vessels.

Fig. 2 is a schematic diagram illustrating the installation at the Salem-Beverly filtration plant. One conductivity cell precedes the fluoride addition, the other follows it at the greatest possible distance—to insure that adequate mixing will have taken place. Leads from these cells connect to the conductivity difference recorder and controller unit located in the laboratory building. Also included in this unit is a temperature recorder. The cabinet containing the conductivity recorder and temperature recorder, installed in the filter plant laboratory, is shown in Fig. 3.

Problems of Interference

There are several real and potential interferences which must be considered when using this method. Those which we have investigated are described below.

Temperature—Conductivity is very closely related to water temperature, and it is necessary that both conductivity cells operate at the same temperature or at a constant differential in temperature between the two cells so that the temperature effect may be balanced out.

The original installation included a temperature difference recorder which was operated for a sufficient period of time to show that there were very minor changes in temperature between the two cells, as was to be expected where they were installed in a single pipeline. After this information was obtained, the temperature instrument was changed to a straight temperature recorder giving the temperature of the water flowing through the plant.

Our instrument does not compensate automatically for base temperature changes in the water, and therefore it is necessary to use a correction curve for temperature when converting readings from electrical conductivity to fluoride.

Lime—Hydrated lime was being applied to the filter effluent for the correction of pH. This chemical is very slowly soluble in water and was fully expected to give erratic results on the fluoride recorder, since it would not be in complete solution as it passed the two electrodes.

Actual trial with the installation for a very short period of time showed this assumption to be correct. It was found necessary to transfer the application of lime to a point ahead of the filters, thereby assuring that the chemical was in complete solution at the time it reached the conductivity cells.

We have not experienced any operating difficulty in the altered application of lime, although at higher doses we would expect some dissipation of color before the water was filtered.

Calgon—Calgon is used for corrosion control and is applied to the filter effluent ahead of the fluoride conductivity cells. The point of location of Calgon was transferred to a point more remote than previously from the upstream conductivity cell.

This chemical is fed as a solution and has very little, if any, effect on the performance of the fluoride recorder. On several occasions Calgon feed has been started, stopped, and changed in rate with barely perceptible changes on the chart record of fluoride concentration.

Chlorine—Chlorine is applied to the water at various points in the treatment process during different seasons of the year; the dosage varies as needed. A usual point of application

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1. International Hydrofluosilicic Acid runs typically 25% acid solution with a guaranteed minimum of 23% H_2SiF_6 by weight.

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is to the filter effluent. Chlorine has had very little, if any, effect upon the sensitivity or accuracy of the fluoride recorder.

Aluminum—Megregian and Maier[2] have described various substances which interfere with the colorimetric test for fluoride. Prominent among these is aluminum.

The interferences attributed to aluminum have been virtually duplicated in trials at our own laboratory. Since aluminum is considered to interfere because it forms a complex with the fluoride ion, it is conceivable that aluminum will affect the results shown by conductivity difference. This is a matter which should have more detailed study.

We are not certain as to whether or not it affects our results. It appears that if there is any effect from aluminum in the filtered water, it would not be greater (and probably would be less) than would be indicated in a colorimetric chemical test for fluoride.

Silica—As described by Babcock and Dobson[3], there is some question as to the interference effect of silica (contained in sodium silico fluoride or present in other forms in the water).

On several occasions during the past six months we have experimented with activated silica as an aid to coagulation. At times we have considered that there might be some effect from this added silica upon the action of the conductivity recorder. However, in most cases the silica treatment was used in order to reduce the residual alum in the filtered water, and it may have been the change in the aluminum concentration which was indicated on our chart.

Incomplete solution of fluoride salts—We believed that our original setup of equipment provided adequate detention capacity, in the dissolving chamber and in the pipeline, to insure complete solution of the fluoride salts before they reached the conductivity cell. There have been a few occasions, especially in cold weather, when there has been some doubt as to whether all of the sodium silico fluoride was in complete solution at the time the water passed the second conductivity cell.

General Operating Conditions

This method of recording the concentration of a chemical compound in water is extremely sensitive, and it was expected to show some drifting, or hunting, of the pen on the record chart. Quite extensive drifting did occur, and studies were made in an attempt to relate it to cycling of chemical feeders, filter rate controllers, or other phenomena throughout the treatment plant.

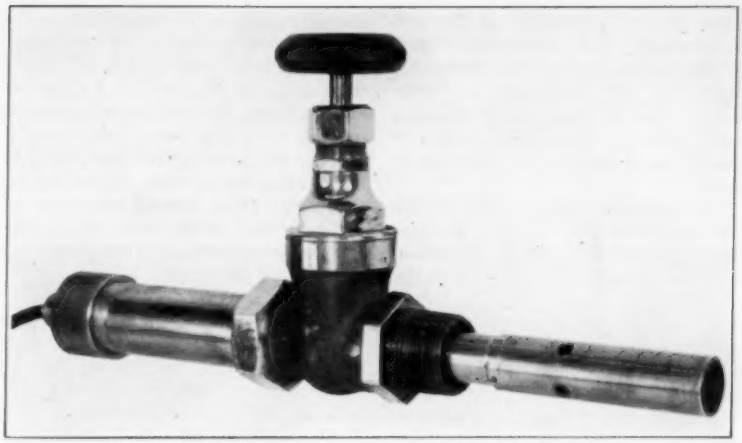

Fig. 1—CONDUCTIVITY cell of standard industrial type is employed

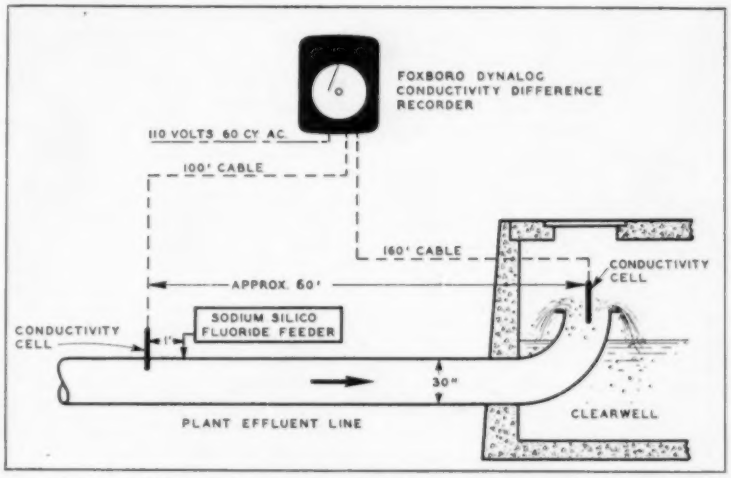

Fig. 2—SCHEMATIC diagram of the fluoride concentration recorder installation

These studies were not successful in locating any specific reason for the fluctuation of the pen arm. We concluded that it might be impossible to get a smooth curve on the chart in filter plant operation where many chemicals were used and where the flow rate was subject to change from time to time.

The neighboring town of Danvers, Mass., was also using sodium silico fluoride to treat its water. The water is drawn from a pond and fluoride is added ahead of the high lift pumps. The only additional chemical treatment is chlorination, which is applied after pumping. The conductivity instrument was moved to Danvers for a test run. It was certain that the water would be of constant quality and the fluoride salt would be completely in solution at the time it passed the second conductivity cell.

In the Danvers test, hunting of the pen was considerably reduced and the zero location remained much more constant. This indicated that where the water supply is constant, an excellent record could be obtained of the fluoride concentration. After the trial run at Danvers, the instrument was returned to the laboratory at the Salem-Beverly filtration plant. It has operated for several months, requiring little maintenance, and has provided a very useful record of the fluoride concentration in the water.

Improved Instrument Installed

A new instrument, including a pneumatic controller, was installed in the laboratory on February 24, 1954. The equipment is illustrated in Fig. 3. Before connecting the control mechanism, the new instrument was used for some time only as a recorder (similar to the original instrument). Hunting of the pen was still somewhat of a problem, but finally was

solved by an adjustable instrument modification. This change did not reduce the sensitivity of the instrument, but did eliminate the wide swing of the pen arm. The instrument then provided neat, readable record of fluoride concentration in the treated water.

The necessary components were then assembled for a system to completely control fluoride application from the recorder-controller unit.

The system used in this arrangement consists of a pneumatic controller integrated with the recording mechanism. The pneumatic controller transmits an air signal (which is in proportion to the fluoride concentration) to a pneumatically controlled valve located in the discharge line from the solution pot of the fluoride feeder. Whenever the fluoride concentration in the water falls below the index point set on the controller, air pressure is built up. The air pressure opens the control valve and discharges more fluoride solution, thereby bringing the system back into balance. Conversely, if the fluoride concentration increases above that point set on the instrument, the valve automatically closes sufficiently to bring the system back to balance.

It is necessary, of course, that the fluoride feeder operate at a rate sufficient to meet the maximum fluoride demand at the maximum rate of water treatment. The controller will successfully prevent any over-dose of fluoride and will maintain the fluoride at the point set, so long as the feeder actually supplys the necessary chemical to the system. If anything should prevent the feeder from applying the chemical in amount sufficient to maintain the fluoride concentration at the desired rate, the recorder chart shows the actual fluoride concentration. When the concentration reaches a point below that desired, a light appears on the indicator panel. Both the light and an alarm system can function if desired.

Relays Control Feeder Operation

A change was also made in the operation of the feeder. The fluoride feeder is now started and stopped by a system of level relays operated by electrodes in the solution chamber. By means of a solenoid valve, these electrodes will shut off the water supply to the solution chamber and also stop operation of the fluoride feeder when the water level in the solution pot reaches a point slightly below the overflow level of the chamber. When the level in the fluoride solution pot drops to a predetermined point, the second electrode causes the feeder and the water supply to start again.

The actual mechanics of pneumatic control have been discussed more thoroughly by Babcock[4, 5]. At our filtration plant, we have experienced no trouble with the pneumatic system, and the electronic system has required little maintenance with the exception of two or three burned out tubes in the early part of development. It has not been necessary to change a tube for at least one year.

The one source of difficulty in making automatic control function was the proper operation of the valve end of the pneumatic control system. In order to secure accurate control of the flow of the fluoride solution, a very small valve of the needle type was required. Considerable experimentation was necessary in order to keep this valve from plugging. We eventually found that mounting the valve on its side prevented the deposition of any insoluable material under the valve seat. Since the valve has operated by automatic control, there has been no accumulation of material which has stopped the flow. We found that the plant operators had been using a broom to clean up small amounts of fluoride chemical around the loading hopper in the storage room, and occasionally a broom straw would break off and go through the feeder. The straws formerly had passed through the system without giving trouble but they were unable to pass the small needle valve of the pneumatic control system. We no longer use the broom.

Charts Illustrate Operation

Three typical charts are reproduced to illustrate the operation of the pneumatic control instrument. Fig. 4 is a chart recorded after the drifting pen problem had been solved, indicating that there is much less "painting" of the charts than was evident in charts reproduced with the original paper[1]. At the time this chart was recorded, the intrument was not operating on automatic control, but was merely recording the fluoride which was being added to the water.

It will be seen that there are various ups and downs in the record; the variations are caused by the flow rate through the effluent line increasing and decreasing, without changes being made in the fluoride feed rate. At 10:15 A. M., the stilling box in the fluoride solution pot was cleaned, thus introducing a fairly heavy concentration of fluoride to the chamber for a short period of time.

Later, at 10:45, the flow rate through the effluent pipe was reduced while two filters were being washed. Again the fluoride concentration in the effluent was increased. After these two clean filters went into service, the flow rate was increased to some extent and the fluoride concentration was somewhat ower than previously.

Still later, at 11:00 P. M., filters were shut down for various periods of time while five of the filters were washed. During this severe reduction in rate, the fluoride concentration was increased to approximately two parts per million, for a period of only 10 minutes.

Fig. 5 is a normal chart recorded after the instrument was operating on automatic control. It will be seen that upon starting in the morning there was a very slight "overshooting," the instrument then steadied down the rate and held the dosage virtually constant throughout the day's run. At 9:25 A.M. the index pointer was moved down-scale for a short period of time to demonstrate its action to a visitor at the plant. At 9:45 P.M. two filters were out of service to be washed. There is a slight indication showing the distance by which the pen can leave the index setting before the instrument changes the fluoride dose, and returns the feed to the normal rate.

Fig. 6 is another chart recorded on a day when the instrument was controlling the fluoride dose. Again, there is evident a typical slight "overshooting" when the plant started in the morning. On this day, some trouble was experienced with the agitator in the fluoride solution box at 7:30 A.M. and again at 1:45 P.M. The chart record shows that such occurrences can be noted very quickly by the operator, and promptly corrected. At 3:45

Table 1
Automatic Fluoride Application

	F-applied	Controller Setting
July 1	.66	0.65
2	.79	0.7
3	.65	0.7
4	.72	0.7
5	.67	0.7
6	.70	0.7/0.9
7	.93	0.9
8	.96	0.9
9	1.07	0.9
10	.99	0.9
11	.92	0.9
12	.74	0.9
13	.81	0.9
14	.78	0.9
15	.96	0.9
Average	0.82	0.82

P.M. fluoride application was stopped by setting the valve to its closed position, using the manual control switch at the recorder; the amount of fluoride being added dropped to zero. Upon restarting, the index point was set to a higher fluoride rate than previously, and the instrument immediately maintained the fluoride concentration at the new index setting.

It should be noted that all of these charts are recorded in terms of electrical conductivity difference. The actual fluoride content is determined from a curve of conductivity difference vs. fluoride for our water.

Operating Experience

Our experience, extending over a period of eighteen months, with recording and controlling fluoride doses by means of an electrical conductivity instrument indicates that this equipment provides a satisfactory method for operating this process in water treatment. Mechanical troubles and electrical troubles have been at a minimum, and the instrument assures accurate control of fluoride dosage.

Table 1 shows the actual amount of sodium silico fluoride applied during the first 15 days of July. The chemical is reported in terms of fluoride ion and is compared to the doses called for by the setting of the controller.

It would be well to describe the difference in concept between this method and the usual method of gravimetric control of chemical feed. In gravimetric control, the chemical feed is actually set by the weight of chemical intended to be applied to a measured amount of water, and the feeder rate can be paced by the flow of water. In the conductivity method, the flow of chemical applied is actually proportioned to the concentration of chemical in the finished water. Regardless of the rate of water flow, if the concentration of chemical changes, the amount of applied chemical is automatically changed to balance conditions as they exist in the water. The automatic controller method does give a check on chemical feeder operation which is not available by the gravimetric method.

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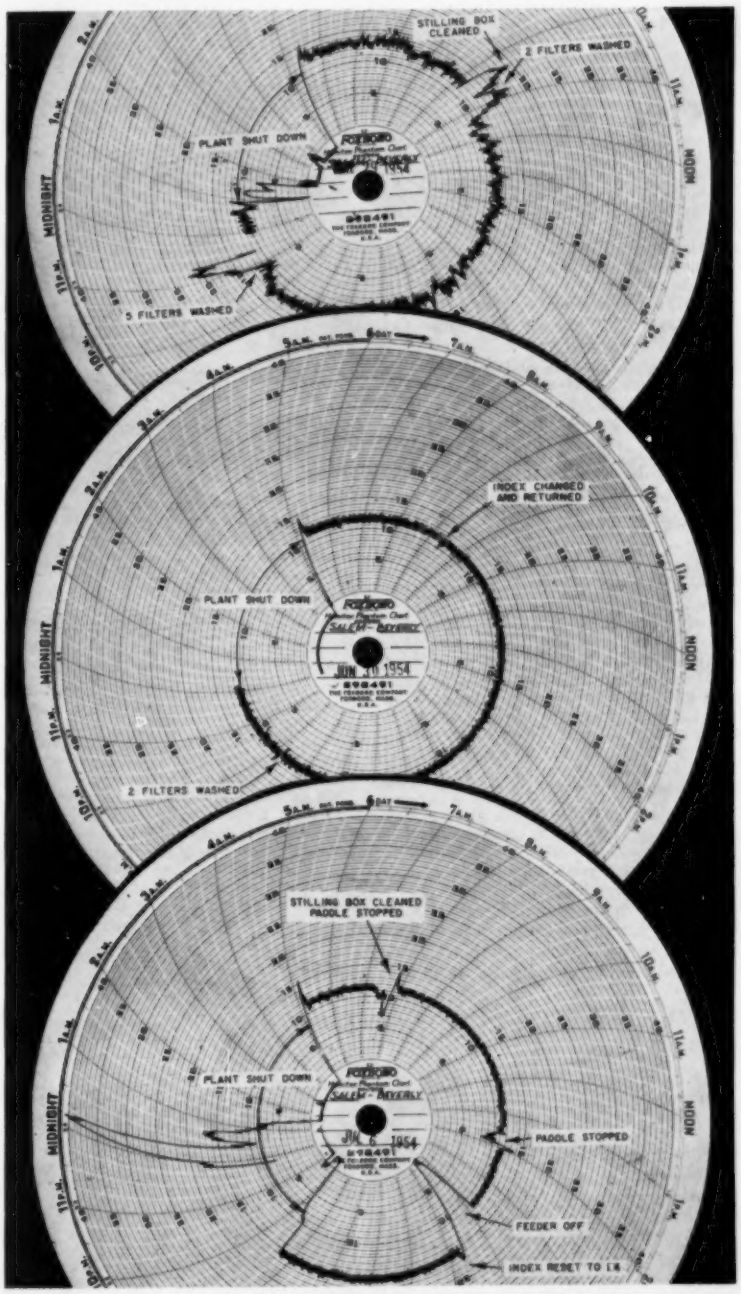


TYPICAL CHARTS illustrate operation

Fig. 3—Record of fluoride concentration, automatic control not operating
Fig. 4—Normal chart record when automatic control is operating
Fig. 5—Chart record illustrating rapid recording and correcting of dosage

Quick Freezing Small Pipes for Repairs

By JOHN L. FORD
Secy. & Treas., The Ford Meter Box Co., Wabash, Ind.

WHEN curb valves on water services have to be replaced or when street widening makes it necessary to lengthen the service to the curb valve, it is a big advantage to be able to shut off the pressure. Shutting off the corporation cock at the main generally involves too much digging and expense to be practical unless it is the only way.

In some water works it has been common practice for many years to temporarily freeze water in pipes to serve as a plug in the line and prevent flow during valve changing or other repair and extension work. I recall my father telling how he used a box about 4 in. square and a foot long with notches in the end to slip under service pipes and then fill with ice and salt. The principal requirement for service pipe freezing is stopping the flow during the process, or at least cutting it down to a rate which will permit freezing. In replacing defective curb valves it is generally possible to cut the flow down far enough.

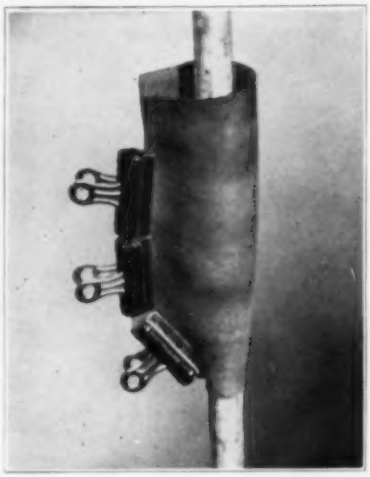
Considering the simplicity and ease of service pipe freezing it has always been surprising that it is not used oftener.

The use of dry ice (solid carbon dioxide) for pipe freezing probably dates from the time when this material first became available. Its principal advantage is that it is so cold that it works amazingly fast. Also it is clean to handle and is now easily obtainable from almost any frozen vegetable distributor or ice cream shipper.

Simple Method of Freezing Service Lines

Here is a quick way to freeze water in pipes with dry ice. The procedure is certainly simple and fast. A piece of old inner tube about 8 in. by 10 in. is centered under the pipe and then brought up and fastened together with wide and strong paper clamps. The rubber should not be stretched tight from end to end but should be a little loose so as to form a pocket around the pipe—see cut.

For freezing a ¾ in. pipe a piece of dry ice about as big as a tennis ball and weighing about one pound is ample. This is placed in a cloth and then pounded into "snow" with a hammer, board or stone. The "snow" is then poured into the rubber pocket and about one-fourth pint of alcohol is poured in on top, the two ingredients making a wet mush which is so cold and makes such good contact with the pipe that the water inside is quickly frozen. Any alcohol, anti-freeze or even rubbing alcohol can be used. Gasoline or naphtha are also satisfactory though these may be hard on the rubber. However, old tire tubes can be had for the asking at most service stations so the cost of the rubber makes no difference and gasoline may be more readily available than alcohol.



Suggested Arrangement for Freezing Vertical Pipe

(To make liquid tight joint around pipe press clay, chewing gum or wax into corner between pipe and bottom clamp.

When the flow in the pipe can be stopped entirely this procedure will freeze the water in a ¾ in. steel pipe solid in from two to five minutes. With a flow of 1/30 gpm. (about one-fourth pint per minute) the flow will stop in about the same time. This flow is more than a drip, coming out of a smooth ended small faucet or small pipe as a steady stream about 1/16 in. in diameter and breaking into drops some three inches below. The experiments on which these results were observed were made with water of about 65° F.; colder water would freeze a little faster. It takes several times as long to freeze a service with dry ice when no liquid is added. Apparently this is because the liquid makes better contact with the pipe and conducts the heat away faster.

In actual work in the trench there may be a small drip from the valve which can be watched to see when the flow stops to indicate that the pipe is frozen.

When there is no leak or drip to watch, the best procedure is to leave the valve closed for five minutes after the dry ice and liquid are poured around the pipe and then open the valve cautiously, keeping in mind that there will be a small amount of water under pressure between the ice plug and the valve which may deceive the operator into thinking the ice plug is not yet solid. If the flow continues, close the valve again before the water thaws much of the ice that has formed, and let the freezing action continue a few minutes longer and again try for flow.

After the pipe is frozen solid it will remain so as long as there is any dry ice left in the envelope and more can be added if desired. After the necessary piping changes have been made the rubber is removed and warm water can be poured on the pipe to thaw it, or a torch can be used. The rubber can be re-used many times and the expense of this method is only 15 cents for material. The time required is only a few minutes in most cases. There is no damage to any kind of pipe by this process, but of course dry ice should never be handled with the naked hand.

If the flow cannot be reduced to about half a pint per minute the pipe cannot be frozen as mentioned above because the warm water passing through keeps a small opening melted through the ice. A longer pocket providing more contact would doubtless freeze a greater flow but it is obviously impossible to stop large flows unless means are available to reduce the leak to a rate that will freeze within a reasonable time.

A Warning

A word of warning should be added about the use of dry ice. The carbon dioxide given off is not poisonous but it can cause suffocation and even death. The small amount used in pipe freezing and the natural ventilation available makes the danger in this work almost negligible. There is little fire hazard with alcohol or gasoline during the freezing because the concentration of carbon dioxide and the low temperature of the liquid prevent ignition.

(1) Pound the dry ice into "snow" in a cloth; pour it into rubber pocket around pipe.

(2) Pour about one-fourth pint of alcohol or gasoline on the "snow" and stir to mix.

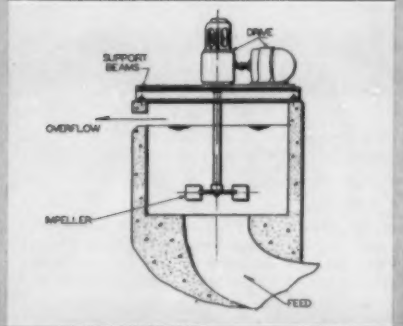
(3) After 3 to 5 minutes the water in pipe is frozen solid; the repair can be made.

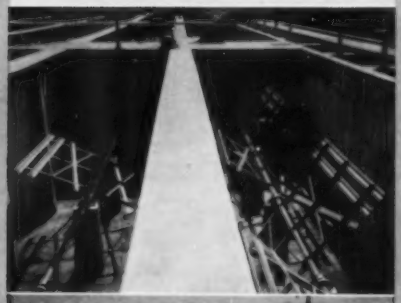
BULLETIN # 6042

Dorr-Oliver

Equipment and Methods for Modern Water Purification and Sewage and Industrial Waste Treatment

An outline of the major equipment units of the complete Dorr–Oliver line for municipal and industrial sanitation arranged in flowsheet order.





EQUIPMENT	DISTINGUISHING CHARACTERISTICS	APPLICATION
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Dorr Pre-sedimentation Thickener Up to 50 MGD and 10,000 tons solids per day per unit.	Raking mechanism for circular tank, designed to collect and concentrate settled material to a central discharge cone.	Particularly adaptable where turbidity exceeds 1,000 ppm. Use results in chemical savings and reduced load on secondary basins.
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Dorrco Flocculator* From 0.1 MGD up. Bulletin No. 6971	Motor-driven revolving paddle wheel elements set in rectangular basin. Gentle mixing causes build-up of uniform flocs of excellent characteristics.	Whenever finely-divided or semi-colloidal solids are present in raw water, the use of Dorrco Flocculators will increase plant capacity and reduce chemical consumption.
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Dorr Clarifiers and Monorakes* From 0.1 MGD to 30 MGD per unit. Bulletin Nos. 6191 and 6001	Both center-shaft and center-pier Dorr Clarifiers equipped with rotating raking arms for round or square tanks. Dorrco Monorake is a balanced raking mechanism for use in rectangular tanks.	Continuous removal of settled solids from clarified raw water, sewage or industrial waste.

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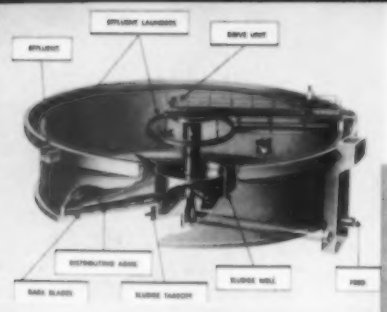

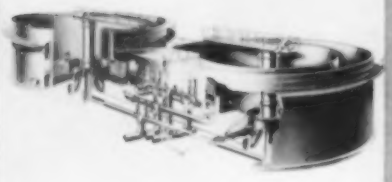

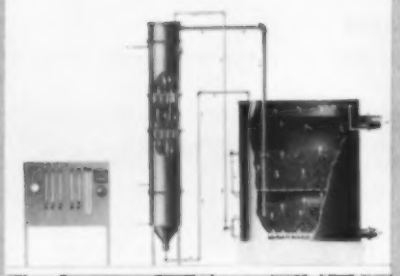

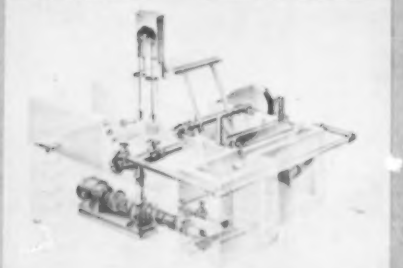

EQUIPMENT	DISTINGUISHING CHARACTERISTICS	APPLICATION
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Dorrco Hydro-Treater® From 0.2 to 30 MGD per unit. Bulletin No. 9041	Complete, self-contained high-rate unit providing for flocculation, thickening, clarification and positive sludge removal in a single tank.	For softening, color or low turbidity removal.
Dorrco Clariflocculator®	See sewage and industrial waste treatment.	
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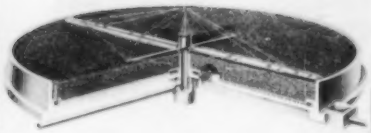
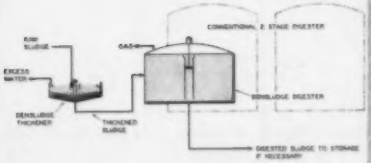
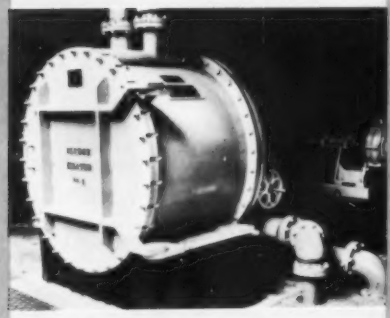
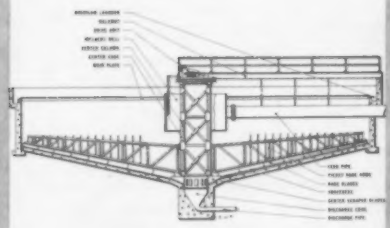
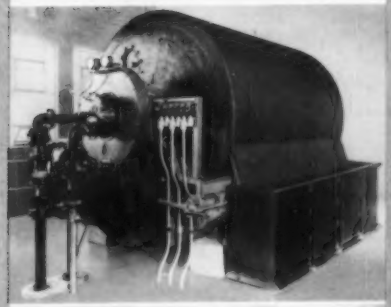
CLARIFICATION		
	See water purification.	











EQUIPMENT	DISTINGUISHING CHARACTERISTICS	APPLICATION
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Dorrco Distributor From 0.1 to 27 MGD per unit. Bulletin No. 6300	Two or four-arm rotary, self-propelled unit for even distribution of liquid wastes over filter bed.	Equally applicable to low or high-rate trickling filter treatment for oxidizing organic matter in solutions.
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SLUDGE THICKENING		
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EQUIPMENT	DISTINGUISHING CHARACTERISTICS	APPLICATION
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Dorrco Clariflocculator From 0.1 to 10 MGD per unit.	Provides mechanical flocculation in inner compartment, clarification and positive sludge removal in outer annular compartment.	For clarifying raw or chemically treated municipal and industrial wastes.
Dorrco Aerator-Clarifier From 0.1 to 7.5 MGD per unit.	Contains cylindrical aeration chamber of steel with partially closed bottom, concentric with Clarifier. Standard sludge raking mechanism. Air introduced by fixed diffuser tubes.	For the preaeration of raw sewage. Grit or heavy solids will not interfere with operation of unit.
Currie Clarsetor Up to 25 MGD per unit. Bulletin No. 6581-C	Combination aerator and clarifier with clarification taking place in round or square central compartment and aeration in outer annular compartment.	For the clarification and aeration of sewage or industrial wastes in the activated sludge process.
Dorr Clarigester* From 0.1 to 1.25 MGD. Bulletin No. 6691-C	Mechanically equipped two-story tank combining clarification in top compartment and controlled, separate sludge digestion in lower compartment.	Ideal for small sewage or industrial waste plants either as sole treatment unit or in combination with other treatment steps.
Dorr Duo-Clarifier Duo-Filter and Duo-Clarigester From 0.1 to 1.25 MGD per unit. Bulletin No. 7312	The "Duo" units are designed for two-stage treatment in a single structure. The Duo-Clarifier provides primary and secondary clarification in one tank; the Duo-Filter consists of two stages of filters arranged concentrically; the Duo-Clarigester provides two stages of clarification plus separate sludge digestion in a single structure.	Particularly adaptable for treatment of domestic sewage from small communities and isolated establishments with contributing populations of over 500 and industrial wastes requiring biological treatment.

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VI. SEWAGE WORKS OPERATIONS

SEWAGE or waste-water is a consequence of modern civilization and communal living. Its disposal without nuisance and threat to public health is mandatory on municipalities. Disposal without treatment to a receiving body of water offers the simplest approach to the problem, but when the receiving waters cannot assimilate the waste without nuisance or menace to health, sewage treatment must be practiced.

The treatment of sewage involves physical, biological, and biochemical processes organized under the unit process concept of chemical engineering. These processes are carried out in structures designed by civil engineers and equipped with mechanical devices, often operated and controlled by electricity. Flow of liquids follows principles of hydraulic engineering and operation control is by chemical and bacteriological tests. As in water works, the problems of financing, rates, and management are important. Therefore, it is obvious that the manager, superintendent, or operator but be a combination civil-mechanical-electrical-chemical-hydraulic-automotive-engineer, chemist, bacteriologist and biologist, with some knowledge of insects, horticulture, finance and statistics.

Sewage Characteristics

Sewage, the used water supply of a community, is almost entirely water, containing 0.1 per cent or less of impurities, but it is this small amount of foreign matter which is so important and needs to be removed. These impurities may be dissolved, colloidal, or suspended solids consisting both organic and inorganic matter. Sewage contains grit, garbage, paper, rags, feces, matches, urine, and various other matter which may come from the home or factory. So dilute is it, however, that these substances are seldom recognizable. In fact, sewage looks more like soapy dish water than anything else, but its minor content of impurities is both the reason for treatment and the source of all operating problems.

Stream Pollution

Water receiving the organic and bacterial impurities in sewage has a limited capacity to "purify" itself, but this capacity is limited by the amount of dissolved oxygen present in the stream and the rate at which it can be dissolved to replace oxygen used up in the stabilization of organic matter. If the organic load exceeds certain limits the water becomes foul and nuisance conditions result. It is then that the matter of stream pollution becomes a factor in determining the extent of sewage treatment required before the wastes are discharged.

Collection

Water is delivered to customers through a distribution system. Used water or waste-water must be collected and removed from the users' premises, and this collection is accomplished by a sewer system, also called a sewerage system. The sewer system consists of house connections to lateral sewers, which lead to main sewers and thence to trunk sewers, from which in turn the sewage is collected by an interceptor (or intercepting sewer) for delivery to a treatment plant or to some body of water.

Each of these sewers is larger than the ones which run into it and must have a capacity sufficient to carry all of the sewage collected by the smaller sewers which it receives. In many older communities, storm water, street drainage and even roof drainage is discharged into the same sewers receiving sanitary wastes. Such an arrangement is called a combined system and presents many problems of treatment and operation. Modern design practice provides two sewer systems wherever possible, one for sanitary wastes and one for storm waters.

Treatment

The purpose of sewage treatment is to reduce the nuisance characteristics of the waste water and eliminate the menace to health. Thus removal of the suspended matter, oxidation of organic matter and killing of bacteria are the fundamental actions involved in sewage treatment.

Primary sewage treatment consists of the removal of suspended and floating matter. *Secondary* treatment utilizes aerobic microganisms which oxidize and stabilize organic matter. The secondary treatment may be accomplished by trickling films of sewage over exposed surfaces of rocks (as in trickling filters) or by blowing air through sewage containing clumps or flocs of microorganisms living and growing in a mixture of fresh sewage and previously treated sewage. Many variations of these two methods of secondary treatment.

Disinfection or the killing of pathogenic or harmful bacteria is practically a necessity where only primary sewage treatment is used. It is also used in many cases as a safety measure following secondary treatment. Chlorine is the chemical most generally used for disinfection.

Solids disposal is an important part of sewage treatment. Heavy inert solids such as sand, cinders, etc. can be easily disposed of as fill. Organic solids teeming with bacteria must be treated to reduce their nuisance characteristics before ultimate disposal. These solids called sludge are usually subjected to a biological digestion process from which a harmless residue (useful for soil conditioning) results. Either raw or digested solids can be chemically treated, dewatered, dried and burned if necessary.

Miscellaneous Operations

Sewage treatment plant operation involves maintenance, laboratory control, management and good public relations. There may also be problems of industrial wastes. Indeed, the subject of sewage treatment and disposal requires broad training and experience of those concerned with it.

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ACTIVATED SLUDGE TREATMENT

BIO-ACTIVATION PROCESS—a patented process combining and utilizing the best qualities of trickling filters and activated sludge in two stages and in such a manner that each stage operates under optimum conditions and at maximum efficiency. Primary treatment is followed by high capacity filters and short period intermediate sedimentation. Here, initial high removals of BOD are obtained before sewage is passed to aeration tanks where activated sludge is developed. Because of the intermediate filter treatment which considerably reduces the strength of the primary effluent, the liquor can be readily handled by the activated sludge process without the usual upsets caused by exceptional conditions and shock loads.

Send for Bulletin 259-B

A Typical Bio-Activation Plant

MECHANICAL AERATION—Consists of a circulating pump with down-draft tube and hydraucone assembly. As liquor passes through the pump, fine bubbles of air are drawn in and intimately mixed with the sewage. This mixture is ejected at high velocity across the tank floor. Consequently, entrained air is distributed uniformly across the tank, and fine air bubbles, rising slowly to the surface, supply sufficient oxygen to maintain the activated sludge process. For large installations, "AMERICAN" Aerators are installed in single, large tanks without dividing walls because the pattern of recirculation sets up hydraulic baffles between the units, thereby eliminating any possibility of short circuits.

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FIXED TUBE DIFFUSERS—Economically increases efficiency of oxygenation, with minimum maintenance. Use of flexible sleeve-type couplings throughout allows easy installation or removal of any section. Ever-increasing cross-sectional area at air inlet reduces friction loss. Porous tubes with gasketed cast iron end covers and tie-rod make tight assembly.

Jet Aerators also available. Write for information.

ROTARY DISTRIBUTORS—Reaction and Positive Drive Types. The Reaction type is manufactured with 2, 3, 4, or 6 arms. In general, the 3 arm distributor has the advantage of minimum wind effect, low starting inertia, and perfect balance. The Positive Drive type is rotated continuously independent of the sewage flow, by a motorized gear reduction unit. It is used under conditions of low available head and wide variations in flow. "AMERICAN" Distributors are equipped with a patented dual oil seal which eliminates troublesome and costly mercury, protects bearing surfaces, and will withstand at least 10′ of water pressure.

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Send for Technical Supplement TV on Telescoping Sludge Valve

GRIT REMOVAL

AMERICAN CAMP REGULATOR—an adjustable control to maintain velocity of sewage flow thru grit channels at optimum rate, regardless of rate of flow thru plant.

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GRIT HYDROWASH—grit washed free of organic matter by turbulent downflow recirculation of liquor in grit hopper.

GRIT ELEVATOR—tube type, totally enclosed for lifting well-drained grit to desired height. Manual or automatic operation.

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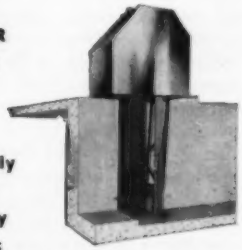
UNIT BAR SCREEN



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MECHANICALLY CLEANED BAR SCREEN AND GRINDER—designed for wide range of channel widths, settings, and arrangements. Grinder attached to sorting tray . . . shredded screenings returned to sewage flow.

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GREASE FLOTATION UNIT—removes grease and oils, produces simultaneous aeration and agitation, and oxidizes objectionable odors.

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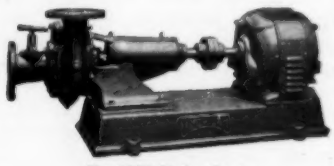

Fig. 5500 Sludge Pump

SLUDGE REMOVAL

POSITIVE FLIGHT CONVEYORS—for rectangular settling tanks.

CIRCULAR CLARIFIERS—for round settling tanks.

SLUDGE AND SEWAGE PUMPS—Fig. 5500 cutting type primary sludge pump. Fig. 5100 enclosed impeller type raw sewage pumps. Fig. 5600 single vane impeller type sewage pumps. Fig. 3400 recirculation pumps. This line of horizontal and vertical pumps ranges in size from 3″ to 18″ inclusive, in capacity from 40 to 10,000 GPM, and in head from 5′ to 85′.

Send for Bulletins No. 237-A, 250-A, 253-A, 261-A

Streams and Sewage Treatment

by DON E. BLOODGOOD

Professor of Sanitary Engineering, Purdue Univ., Lafayette, Ind.

A LARGE percentage of the water used by municipalities in the United States is obtained from surface supplies. It is necessary to control in these surface waters the concentration of constituents that make it impossible to prepare a safe and economical finished water. A considerable amount of organic debris does enter streams, and must undergo decomposition if it is not to accumulate in prohibitive amounts. This discussion will review the factors affecting decomposition, as well as the importance of maintaining streams of high quality.

Natural Purification in Streams

The decomposition that takes place when organic matter is discharged into surface water is sometimes considered to be unnatural. In reality, decomposition is a normal method used by nature to reduce the concentration of solids remaining in water.

If decomposition in streams is a natural procedure, it may well be asked, "Why not let nature carry on in her own way?" This would be the very thing to do if decomposition could take place without harming or offending human beings.

The public health is endangered when discharged organic wastes contain pathogenic bacteria. Organisms that live on or in the warm-blooded animals may be harmful to others of the same group. It is also known that few of the pathogens (disease producers) multiply in streams or lakes. Phelps[1] has reported that there is a rapid decrease in the disease organisms once they are discharged into surface waters. Table 1 shows the decrease in numbers of organisms with time.

The environment in a stream is not ideal for the growth of the disease-causing organisms. The decrease in bacterial numbers with time indicates natural purification of the water. It is not safe or advisable to depend upon natural purification, however, because during the period prior to death of the last pathogen some person may consume the water. If the water has not been made safe by treatment, the health of the user will be endangered.

There is more involved in the natural purification of streams than the death of bacteria. Streams receiving sewage will contain organic solids as well as bacteria. It has been previously pointed out in the preceding series that the decomposition of organic matter in streams may cause a nuisance. This will occur if the available oxygen is not adequate to meet the needs of a growth of bacteria sufficiently large to consume the organic solids. When the concentration of solids in the water is *less* than that amount needed to support a growth of bacteria which will use the oxygen in the water faster than it can be replaced from the atmosphere, then there will be dissolved oxygen remaining in the water.

TABLE 1

Death Rate of E. *Coli* in the Ohio River

Warm Weather		Cool Weather	
Days	% Dying	Days	% Dying
0	100	0	100
2	90	2	85
4	99	4	95
6	99.5	6	97
8	99.2	8	98

Reaeration in Streams

According to Phelps[1], Stearns stated in 1890 that stream flows of less than 2.5 c.f.s. per thousand sewered population was insufficient to prevent offensive conditions, and that a stream flow of 7 c.f.s. would practically guarantee a satisfactory dilution.

Seven cubic feet per second is 37.7 million pounds per day (7.0 c.f.s. $\times$ 60 sec./min $\times$ 1440 min/day $\times$ 7.5 gal./c.f. $\times$ 8.33 lb./gal. $\div$ 1,000,000). The B.O.D. per capita is .167 pounds or 167 pounds for one thousand persons. The solubility of oxygen in fresh water 9.2 ppm. at 68° F. In 37.7 million pounds of water there would be (37.7 $\times$ 9.2) 347 pounds of oxygen. If there were no reaeration of the stream (and there always is), 167 pounds of oxygen would be used and (347 — 167) 180 pounds would remain in the water. The dissolved oxygen content would be (180 $\div$ 37.7) = 4.8 ppm.

Aeration of the water in the stream takes place quite rapidly, particularly if the oxygen content of the water is considerably below the saturation point. Exposing a water surface to the air permits oxygen to enter the water very readily. It may be useful to think of the oxygen molecules as bullets flying around freely in the air. When they hit a water that is not saturated with oxygen they are not readily returned to the atmosphere. However, when the water becomes saturated, the rate of oxygen returning to the air is equal to the rate of oxygen entering the water.

Oxygen Concentration Variation

Turbulent water such as that flowing over rough stream beds, over dams, and in very shallow streams,

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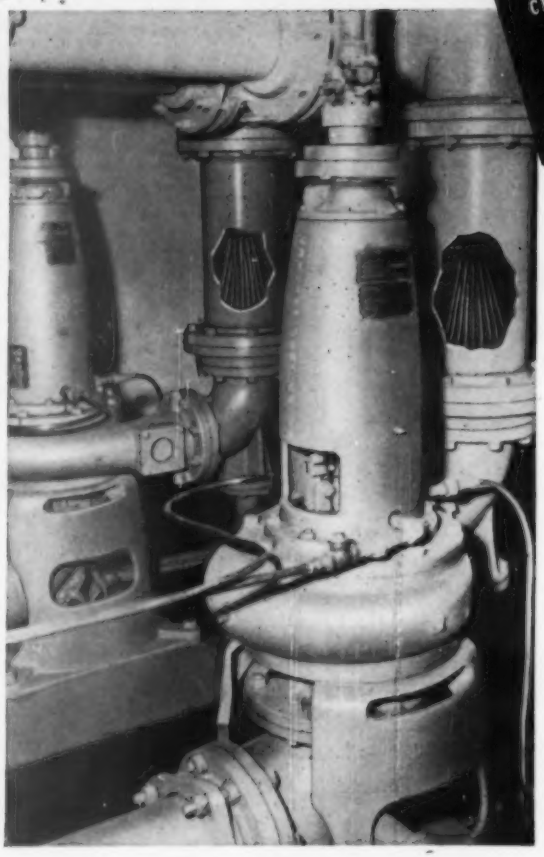

Flush-Kleen sewage ejectors can't clog because rags never reach the impeller. Specially designed strainers in the discharge line retain all coarse matter. Sewage flows over the strainer and through one of the pumps to the wet well. When the pumps operate alternately they pump only strained sewage. No rags or coarse material ever pass through the pump casing. Each strainer is automatically flushed clean during its pumping cycle.

One of 11 Flush-Kleen sewage ejector lift stations installed in the City of Portland, Oregon. The discharge line has been cut away to show the strainer. These stations were designed by Stevens and Koon the Engineers for Portland Sewerage Project.

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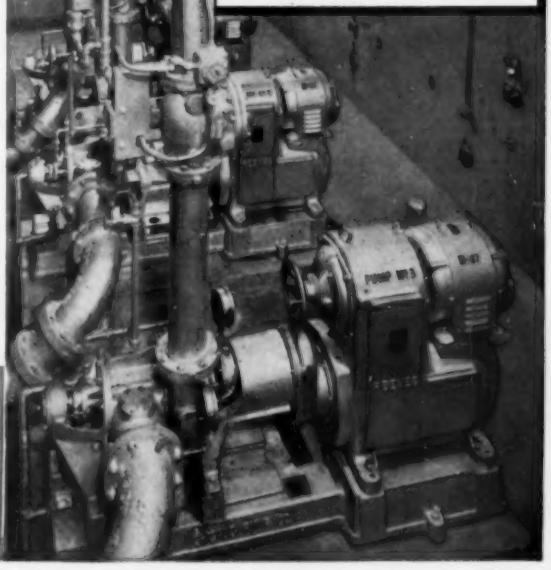
OVER 8,000 IN SERVICE



Scru-Peller pumps are designed specifically for pumping primary sludge, are positive in operation and truly clog-proof.

Continuous multiple shearing action is provided by stellited cutting edges of the screw and eight stellited cutting bars positioned in the screw and pump housings.

Heavy-duty ball bearings at each end of the screw and impeller shaft eliminate strain and vibration, permitting pump to withstand sudden and severe overload shocks.

Three of the 27 Scru-Peller pumps installed at the Hyperion Sewage Treatment Plant, Los Angeles, California. Board of Public Works and Metcalf & Eddy, Engineers.

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readily picks up oxygen. In many instances where oxygen is being consumed by bacteria in oxidizing organic matter, the oxygen is being replaced from the air at a rate that maintains the dissolved oxygen at or near the saturation point.

If the oxygen cannot be supplied to the stream as rapidly as it is being used, the oxygen soon disappears and the body of water is then said to be septic. Once a body of water has become septic the decomposition of organic matter does not stop, but rather a different type of decomposition takes place in which the oxygen is obtained from the organic constituents. Septic action is termed anaerobic decomposition. Anaerobic decomposition is usually taking place in the sludge banks that form in streams which receive organic polluting materials.

The quantity of oxygen that can be held in the water of a stream depends upon the temperature of the water. The salt content of water is also a factor that determines the concentration of dissolved oxygen. Table II shows that the higher the temperature the lower the concentration of oxygen required for saturation, and the higher the salt concentration the lower the saturation point[2].

The Stream Flow Factor

The Stearns figures on the rate of flow of a receiving stream and the quantity of sewage discharged certainly indicate that rate of flow is very important in determining the intensity of pollution. The amount of dissolved oxygen present in water is an indication of the severity of the pollution. Table III gives data collected on White River below Indianapolis some years ago[3]. It shows that the dissolved oxygen was as high as 11.8 ppm when the flow in the stream was 1471 c.f.s., and that it was as low as 0.3 ppm when the flow was 324 c.f.s. Table III shows that rate of flow has an effect on the dissolved oxygen. There are other factors, such as temperature and B.O.D. load, that must also be taken into account if an exact mathematical relationship between stream flow and dissolved oxygen is to be established.

TABLE II
Saturation of Water With Oxygen

Temp. °F.	D.O. ppm	D.O. ppm 2000 ppm chlorides
32	14.6	11.3
41	12.8	10.0
50	11.3	9.0
59	10.2	8.1
68	9.2	7.4
77	8.4	6.7

TABLE III
Stream Flow and Dissolved Oxygen
White River, Below Indianapolis, Ind.

Month 1933	Temp. °C.	D.O. ppm	Thousands of Lb. BOD/Day	Flow in River c.f.s.
January	7	10.5	36.0	3337
February	1	11.8	35.4	1471
March	7	9.1	31.6	4494
April	12	8.8	41.3	3559
May	18	7.2	53.3	7494
June	26	2.8	55.1	1036
July	26	0.2	40.8	436
August	26	0.5	46.2	436
September	25	0.7	46.4	641
October	17	2.3	31.4	454
November	13	0.3	42.8	324
December	9	1.0	36.4	415

Temperature Factor in Streams

An elevated temperature, in addition to decreasing the amount of oxygen in water, also increases the activity of microorganisms that are decomposing organic matter. The result is that oxygen is used more rapidly in the summer than in the winter. Table IV illustrates the relative rate of decomposition at several temperatures[4]. The figures in the table show that the rate of decomposition at 62° F. is twice as fast as it is at 35° F.

Stream Quality and Plant Operation

The preceeding discussion shows the effect of temperature and stream flow on the apparent condition of the stream. Perhaps comment on the importance of temperature and stream flow to sewage plant operation is in order.

Babbitt[5] reports that the removal of B.O.D. in primary sedimentation treatment plants to be 37 per cent.

In considering primary treatment only (and there are many plants that provide only primary treatment) it is reasonable to believe that this degree of treatment usually does remove enough B.O.D. in the summer when the stream temperature is 70° F. or more. From Table IV it can be seen that the activity in the stream would be much less at a lower temperature. In fact, if primary sedimentation removed 37 per cent of the B.O.D. during the warmer period, the stream might be expected to have about the same dissolved oxygen content as if primary units were by-passed during the time the stream was at a temperature of about 55°. It is true that the solids settled out in the stream might form sludge banks. The importance of considering the temperature factor before deciding when to make repairs to a sewage plant can readily be seen.

Streams and Public Health

Sewage-contaminated water can be so treated that the resulting product is suitable for human consumption. In purifying a contaminated supply, however, there always is the likelihood that some day some pollution may get through the water treatment plant without adequate purification. The chances of producing a safe product therefore, are much better if the raw water supply contains relatively few pathogenic bacteria.

The bacteria are removed from sewage in various treatment processes. Some bacteria are attached to solids and are removed when the solids settle out. Single bacterial cells are probably coagulated into clumps in the activated sludge and trickling filter processes. Chemical coagulation, no doubt, helps in the removal of some bacteria. Care must be taken to see that the bacteria are destroyed after removal from the sewage with sludge solids. Most disease organisms die in the foreign environment of the sew-

TABLE IV
Temperature and Rate of Decomposition of Organic Matter in Streams

°F.	Relative Rate of Decomposition	°F.	Relative Rate of Decomposition
35	1.000	60	1.892
40	1.137	62	2.000
45	1.292	65	2.155
50	1.468	70	2.450
55	1.666	75	2.790

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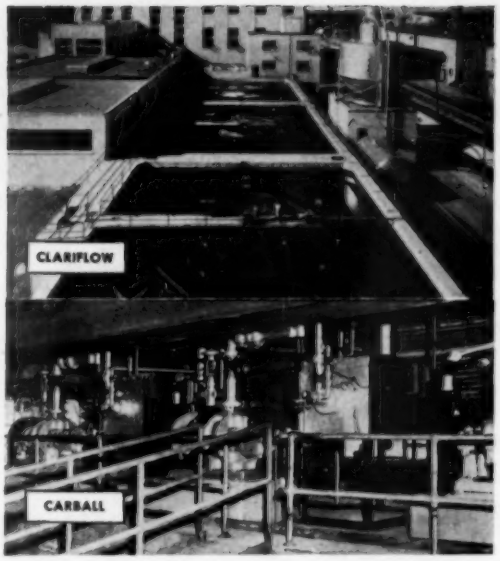
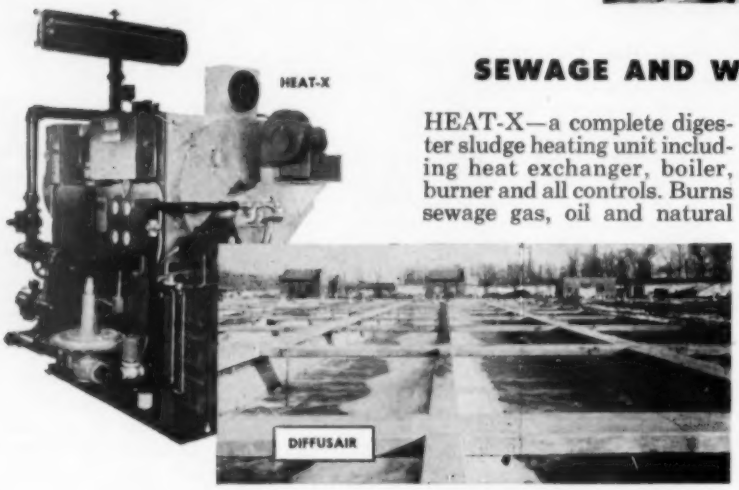
Equipment for All Water, Sewage and Waste Treatment Processes



WATER TREATMENT

CLARIFLOW—a short retention, vertical rise clarification unit combining chemical homogenizing, flocculation, clarification and positive sludge removal for softening and turbidity, color and algea removal. Designed for rectangular, square or circular basins.

CARBALL—produces a clean, tasteless CO_2 gas for carbonation. Burns either oil or gas at high temperature and pressure resulting in dry, clean CO_2 suitable for direct diffusion into carbonation chamber.



SEWAGE AND WASTE TREATMENT

HEAT-X—a complete digester sludge heating unit including heat exchanger, boiler, burner and all controls. Burns sewage gas, oil and natural gas, singly or in combination. Absolute and independent control over each function of sludge heating.

DIFFUSAIR—aeration equipment for mixing and oxygenation of tank liquors. Self cleaning air Spargers do not clog or cause back pressure build-up on blowers. High rate tank turn-over and oxygenation results in greater plant capacity.

INDUSTRIAL LIQUIDS

INDUSTRIAL THICKENER—adapts the CLARIFLOW principle to blast furnace flue dust thickening, oil separation, paper stock reclamation and other applications. Permits reuse of process water and reclamation of valuable waste on many industrial installations.

COLLECTORS—for sludge removal in rectangular, square or circular sedimentation basins. Wide range of capacities and sizes to meet all water, sewage and industrial treatment requirements. Designed to suit the most exacting specifications.

WALKER PROCESS EQUIPMENT INC. · Aurora, Illinois

age plant (the digestion tanks, etc.), however, it is not possible to be sure that all dangerous organisms are destroyed unless the sludge solids are heated to a temperature sufficient to kill bacteria.

Streams and Fish Life

The number of pounds of fish that can be grown per year in a given volume of water depends upon the food supply available, and how satisfactory the environment is. It has been pointed out that the decomposition of organic matter in streams is accomplished largely by microorganisms. The mocroorganisms become food for the larger forms of life and eventually fish use either plants or crustacea for food.

If decomposition has altered the environment by lowering the dissolved oxygen to a point where there is not enough remaining to support fish life, then the fish will die. However, if the decrease in oxygen is not enough to harm the fish, then the fish should appear in greater numbers or size because of the increase in food that is available from organic matter.

Katz and Gaufin[6] have reported that they found pollution may be detrimental to fish even when the dissolved oxygen concentration is adequate. They believe that the pollution is not directly responsible for fewer numbers of fish in water with ample oxygen, and they are of the opinion that pollution so changes the flora in the stream that there may not be suitable food in certain parts of the stream for the fish.

Southgate[7] has reported that rainbow trout are killed in a short period at an oxygen concentration of 2.0 ppm at temperatures between 15 to 17° C. Trout are the most sensitive of all fish to oxygen deficiencies. Extensive studies have been carried on in recent years by the National Council for Stream Improvement (of the Pulp, Paper and Paperboard Industries) on the effect of oxygen concentration on various fish. The Aquatic Life Advisory Committee of the Ohio River Valley Water Sanitation Commission has said that well-rounded warm water fish populations require at least 3 ppm of oxygen at all times, and that for sixteen hours per day the water should contain not less than 5 ppm.

Algae Growth in Streams

Algae, like other plants, grow best when fertilized. A stream that receives nitrogenous materials soon turns them into plant food. Thus, the natural purification that takes place in a stream provides food for algae. Algae are plants which give off oxygen in the sunlight and use some oxygen in the dark. The exact effect of algae on the stream condition is not easily predicted, because of fluctuations in numbers of algal cells and the hours of sunlight that can be expected.

The algae can, in bright sunshine, produce and give off enough oxygen to super-saturate the water. A very good idea of the variation in dissolved oxygen in water that may be expected in a day at one particular point is given by the data presented in Table V.

TABLE V
Variation in Dissolved Oxygen Over 24-Hour Period
Clearwater Lake, Waconia, Minn.

Time Hour	Dissolved Oxygen, ppm	Time Hour	Dissolved Oxygen, ppm	Time Hour	Dissolved Oxygen, ppm
10 A.M.	3.1	6 P.M.	10.5	2 A.M.	6.5
11	3.9	7	10.3	3	5.3
12 Noon	4.5	8	11.6	4	4.6
1 P.M.	5.2	9	11.1	5	3.7
2	6.6	10	9.8	6	2.1
3	5.1	11	9.2	7	3.0
4	5.1	12 Mid.	11.3	8	2.7
5	9.3	1 A.M.	7.6	9	1.6

The data given in Table V illustrate two things: (1) algae can add large amounts of oxygen to a stream, and (2) it makes a great difference at what time of day a sample is taken to determine the dissolved oxygen[8]. Certainly these data show that the seriousness of the pollution in this lake could not be determined by taking a sample in the afternoon. The indications are that algae usually will produce more oxygen in the daytime, by the process known as photosynthesis, than they will use up in the darker hours by respiration.

Sludge Banks in Streams

Sludge banks are formed in streams when the settleable solids in the water are deposited at locations where the velocity of the water is low enough to permit deposition. Sewage or industrial wastes not treated by primary sedimentation are sure to produce sludge banks unless the stream is flowing with a high velocity. Dissolved and colloidal solids also may form sludge banks in streams if these materials are transferred into settleable solids by microorganisms. Therefore, treatment in addition to primary sedimentation may be necessary in order to prevent the formation of sludge banks.

Requirements for Pollution Control

If pollution control is to be enforced for the preservation of stream quality, then the regulations should indicate the condition of the stream that must be maintained rather than the quality of water that can be discharged into the stream. It seems essential also that all pollution control laws should in some way limit the discharge of settleable solids, bacteria, dissolved organic matter and those substances that are considered to be toxic.

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If you want a truly "Never Clog Pump" specify as follows:

"Pump shall be of the non-clogging vortex type with recessed impeller mounted completely out of the flow path between pump inlet and discharge connections to enable passage of solids particles equivalent to discharge pipe diameter."*

*Taken from consultants specifications for sewage and sludge pumps.

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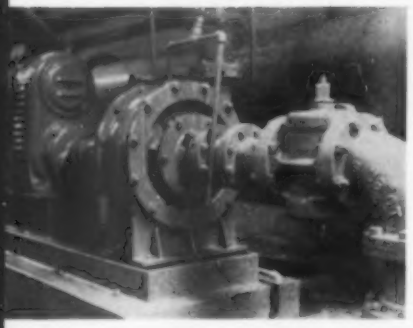
Unattended, continuous operation is the standard operating procedure with Wemco Torque Flow Solids Pumps. Bar screens are eliminated. Frequent inspections are not required. Costly maintenance is eliminated. "Never clog operation" is inherent in the pump's design.

At Torrance, California

General Specifications:
Sizes: 3" through 8"
Material: Cast Iron
Capacities: 50 GPM to 2500 GPM
Heads: Up to 100'
Necessary Clearance Adjustment: None
Models: Horizontal or Vertical (Most sizes)
Drive: V-Belt, Varidrive or direct connected (Most models)



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Sludges with high percentage of solids are handled without blockage. Suction lifts are extremely high at both high and low volume. Long wear life of parts and complete freedom from clogging on rags and fibers prevents down time losses and high maintenance.

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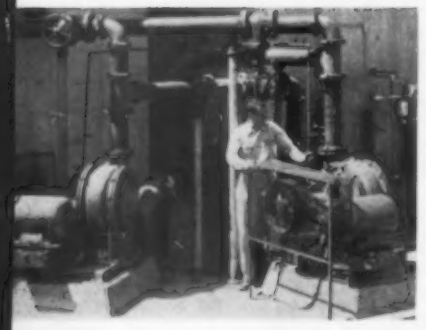
Size: 2" through 8"
Material: Cast Iron or Ni-Hard
Capacities: 50 GPM to 2500 GPM
Heads: Up to 100'
Necessary Clearance Adjustment: None
Models: Horizontal or Vertical (Most sizes)
Drive: V-Belt, Varidrive or direct connected (Most models)



FOR GRIT HANDLING OR DIGESTER CLEANOUT:

Wemco Solids Pump never clogs either in continuous or intermittent operation. Long wear life and no blockage combine to provide the ultimate in overall low cost material handling.

At Los Angeles County, California

General Specifications:
Sizes: 2" through 8"
Material: Ni-Hard
Capacities: 50 GPM to 2500 GPM
Heads: Up to 100'
Necessary Clearance Adjustment: None
Model: Horizontal only
Drive: V-belt or Varidrive

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Sewage Pump Maintenance and Operation*

by GEORGE STRUDGEON

Asst. San. Engr., Chicago Pump Co., Chicago, Ill.

PUMPS ARE the heart of the modern sewage treatment plant. Without their faithful operation treatment facilities large or small, simple or complex, would soon be uninhabitable. In order to keep this heart pumping, an effective protective maintenance program must be carried on. It does little good to start a program after a major breakdown occurs. Operating personnel must know at all times the condition of the plant equipment and immediately correct weaknesses.

Proper care and maintenance means good housekeeping. It is easier to keep equipment clean and in repair than it is to make emergency repairs when everything is covered with grease, dirt, or sludge and the various parts are rusted together.

A program of regular maintenance should be set up. One of the easiest ways to do this is to make a chart or card file showing the required maintenance operations, with a place provided to check off each item when the work is done. This chart will provide a method of reminding the responsible party when oiling, greasing and inspecting should be done, and will also provide a record of the maintenance work.

The operator should familiarize himself with the working of each piece of equipment in the plant. This can be done by studying the operation literature supplied by the equipment manufacturer. If this literature cannot be located, the operator should write for it. These booklets will also form a basis for making the maintenance chart for the plant. Cuts and drawings of the various pieces of equipment should be kept on file for reference. This material also can be obtained from the manufacturer. A drawing showing the location of all underground structures and pipe work should be kept on file for ready reference in case of trouble.

Pump Lubrication

Nothing will cripple the sewage treatment plant more quickly than a breakdown of pumping equipment. Complete understanding of pump construction and function, together with periodic inspection and repair, are essential to avoid breakdowns.

A sound maintenance program for pumps and pertinent accessories should be developed, and a regular inspection schedule adopted based on actual operating experience. To insure the best operation and care of pumps, weekly inspection and maintenance should be made of the following:

1. Bearings, for heat and noise.
2. Motors, for starting and operating speed.
3. Control equipment, for cleanliness and condition.
4. Pump operation, for vibration and noise.
5. Packing glands, for excessive leakage.

Examination of a centrifugal pump reveals that it consists essentially of only one moving part, an impeller retating in a casing. The impeller is supported on a shaft, which is in turn supported by a thrust bearing and one guide bearing. Vertical dry pit and horizontal type pumps require one guide bearing, whereas submerged type pumps require two or more bearings, depending on the depth of the wet well.

Vertical dry pit type pumps are constructed almost exactly the same as horizontal pumps. The bearings are generally of the ball type. Scrupeller pumps are fundamentally the same as horizontal centrifugal pumps, except that a stellited screw, cutting bars, and cutting ring are mounted on the suction side of the impeller for cutting up the solids before they reach the impeller.

Submerged type pumps are constructed differently from centrifugal pumps. The thrust bearing is of ball bearing construction and generally is located above the motor floor level where it will be free from floor drainage and sweepings. The pump casing, guide bearings, and shafting are extended into the wet well. Ball bearings cannot be used for guide or intermediate bearings because there is no effective means for sealing the bearings from the sewage, which would cause corrosion and rust. For this reason, submerged type pumps usually are built with sleeve type guide bearings of bronze.

Packing

One particular packing cannot be recommended for all uses. The type of packing that should be used will depend on the operator and variations in operating methods, conditions, and requirements.

Metallic and semi-metallic types of packing, together with graphite-impregnated soft asbestos, and leather, are commonly used in sewage pumps.

Soft asbestos impregnated with graphite is the most generally used packing, particularly in centrifugal and plunger type pumps. It definitely should be used where grease or water seals are not provided. On the other hand, metallic or semi-metallic packing should be used only where water or grease seals are used.

Packing containing rubber generally is not recommended because rubber has a tendency to swell when in contact with sewage.

Lubrication of the packing increases pump efficiency and reduces friction to a minimum, prolongs the packing life, and controls leakage without undue gland pressure. Where grease lubricants are used a generous quantity should be applied when the packing is installed. Thereafter, the lubricant can be applied by a hand pressure grease gun. The ideal way is to use a forced feed lubricator, applying a small but continuous amount of grease at a constant pressure.

Since the packing in the stuffing box rubs against the shaft, it is just as important that it be lubricated as the bearings. In pumps handling dirty water, the packing is lubricated the same as the bearings. In pumps handling clear water, the packing is lubricated internally with the water pumped. However sewage contains grit and, therefore, cannot be used for lubrication.

Grease is used but seldom with complete success, because some grit invariably works back into the grease, imbeds in the packing, and forms a fine abrasive cloth, which soon wears out the packing and shaft sleeve. An external supply of water for the seal is the most effective lubricant.

If a grease seal is used, and the pump head does not exceed about

*Reprinted from SEW. AND IND. WASTES, 27: 506 (1955)

20 ft., it should be fitted with a spring-loaded pressure type grease cup. Grease should be forced through the packing daily at a rate of 1 oz. per day. If the head is greater than 20 ft., spring-loaded pressure grease cups are not very effective. In such cases, a hand type grease gun should be applied daily.

If a water seal is used the pressure should be greater than the operating head of the pump. This pressure may be secured by a float controlled tank, located at the highest point of the building, or with the aid of a small pump. Seal water should never be obtained by direct connection with a drinking water supply, because of the danger of cross connections.

The life of the packing and shaft sleeve depend almost entirely upon the effectiveness of the grease or water seal. There should be a slight leakage of water from the packing box when the pump is running, to keep the packing cool.

A packing gland should never be tightened more than necessary. Finger-tight should be ample; otherwise excessive pressure will cause the shaft sleeve to wear rapidly and the tight packing will act as a brake band, resulting in higher power consumption.

If the stuffing box leaks excessively, remove the packing and examine the shaft sleeve. If the shaft sleeve is badly grooved or scored, it should be replaced or repaired immediately. Otherwise, the stuffing box will continue to leak excessively and regardless of how it is repacked, the packing life will be short.

When the packing becomes worn remove it entirely and thoroughly clean out the stuffing box. It is bad practice to use part new and part old packing. When repacking it is important that the first two layers are properly in place, before more is added. If this is not done, the bottom layer may be forced in unevenly and may leave a pocket to collect grit. Packing should be installed with butt joints staggered around the shaft.

Wet Wells

The size and shape of the wet well bottom are very important. If it is too flat or too large, solids will collect in the bottom and become septic. This condition may cause the presence of objectionable odors, increase soluble B.O.D., or upset the treatment plant process.

The purpose of the wet well is not to store sewage, but to provide a suction well for the pumps. Some wet wells make excellent primary tanks and defeat their original purpose.

In many cases, wet wells, which are entirely too large and function as septic tanks or primary tanks instead of as suction chambers for pumps, affect the degree of purification. Many operators have remedied this problem by cutting storage capacity through the construction of brick walls or concrete fillets, or by shortening the draw-down.

The size of the wet well should be based on the pump capacity. The active storage capacity or draw down should be equal to 1 to 1½ times the pump capacity.

Regardless of the size, shape, and type of wet well, it should be periodically drained, cleaned, and flushed with water under pressure to remove all deposits and floating solids. Grease that congeals on the walls will break loose in large pieces causing the suction line of the pump to clog, or preventing the float from operating.

When a new sewer system or section is put into service, the wet wells frequently receive large quantities of sand with the sewage. This sand should not be pumped out with the sewage pump, but should be removed with buckets as often as inspection indicates the need. If the sand is pumped out with the sewage pumps, the operator can expect earlier maintenance troubles. When effective water seals are not used the sand will get into the stuffing box packing and soon wear out the packing and pump shaft sleeve. On submerged type pumps this causes the lower sleeve bearings to wear out in a few weeks.

Electrical Control Equipment

Practically every motor is protected by a fused mainline switch and an across-the-line type starter. In addition, float switches and other control equipment may be required to automatically start and stop the motors. The fuses and thermal units used should comply with the National Electric Code or local code recommendations. The fuses and thermal units are generally rated at 125 per cent of the nameplate amperage.

The fused mainline switch and starter protect the motor against "burn out" from short circuits, grounding, high starting current, over-load, phase failure, and low or high voltage. When new motors are installed the size of the heating element in the starter should be checked against the current requirements of the motor. A starter with an oversized heating element, or with a "jumper" around the element, does not furnish protection.

If a starter with thermal protection is cutting out frequently, and the trouble cannot be located in the mechanism, location of the starter should be checked. Perhaps it is located too close to a radiator or some other source of heat. In these cases the manufacturers may recommend use of the next size thermal unit.

Every six months, the starters should be checked to make certain the tripping element is not corroded and the motor has protection. All parts should be checked for clearance and freedom of movement. If the contact points are pitted, worn, or arcing, the tips should be renewed or filed smooth, treated with petrolatum, and adjusted or lined up properly. Seriously pitted contact points may burn out the motor if they cause the motor to start and stop too frequently.

When a starter trips out, the cause must be found and corrected before the starter is reset. The following checks will help to locate the trouble:

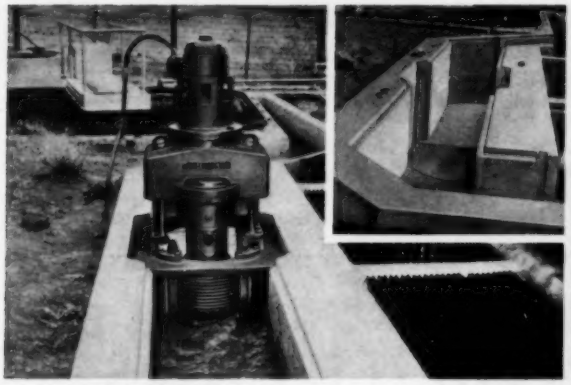
1. The pump shaft should be turned by hand to see that it is free.
2. Wiring and controls should be inspected for loose connections.
3. Contact points should be checked for wear, pitting, or arcing.
4. Brush-type electric motors need to be checked for sparking while starting or operating, and for sticking brushes.
5. Fuses and thermal overloads should be checked for correct rating.
6. The location of fuses and thermal overload units should be checked with respect to the affect of nearby heat sources.

The switchboard should be inspected frequently and kept clean. Vibration may cause loose terminal connections, when least suspected. The insulators should be wiped clean to prevent flashover to the ground.

Dirty contacts are costly power consumers. An operator of a 0.5-m.g.d. plant was surprised to find a large reduction in his monthly power bill after thoroughly cleaning all contacts, fuses, and fuse holders.

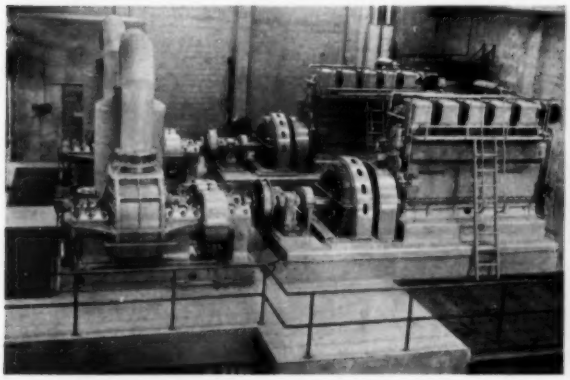
Motors

Three-phase, squirrel cage motors are widely used in sewage treatment plants. These motors require little attention under average operating conditions. Bearing housings are packed with sufficient grease before leaving the factory to last approximately one year. Too much grease causes bearing trouble, due to excessive friction, or damage to the motor windings

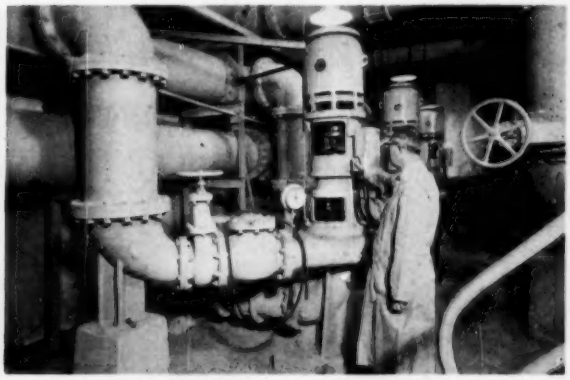


COMMINUTORS. Since raw sewage flows straight through in the Worthington design, the comminutor can be installed in a simple rectangular channel (inset) without expensive masonry work. This one is located at Klamath Falls, Ore.

MIXFLO PUMPS. Available in sizes from 2 MGD to over 300 MGD, Mixflo pumps have non-clogging sewage-type impellers for passing large solids. This one handles raw sewage in the new Salem, Ore., Treatment Plant.



DUAL-FUEL ENGINES. Operating on oil or gas or any combination of both, these Worthington dual-fuel engines drive blowers for the Little Ferry, N. J., Treatment Plant of Bergen County Sewer Authority.



FREFLO PUMPS Available in sizes from 100 GPM to 5 MGD, these Worthington Freflo pumps in the Bethlehem, Pa., Sewage Disposal Plant offer maximum freedom from clogging.

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Some of the sewage treatment plant equipment built by Worthington include: pumps; gas, dual-fuel, and diesel engines; vacuum pumps; air and gas compressors, and comminutors.

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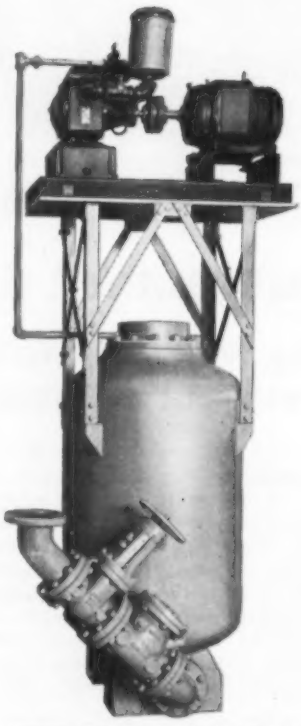
The Modern, Efficient Way to Lift Sewage

30 to 500 gpm single and twin units for discharge heads up to 150 ft.

Duplex Sewage Ejector, showing inlet piping.



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Blackburn-Smith Pneumatic Sewage Ejectors have ended screen and pump cleaning in hundreds of sewage booster stations. For over 60 years, Blackburn-Smith Ejectors have proved their economy, efficiency, and reliability under all conditions.

Blackburn-Smith Ejectors are preferred by engineers because

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Exclusive Blackburn-Smith Features

Only the Blackburn-Smith Pneumatic Ejector System, with or without air receivers, offers the following choice of controls:

1. **Float and electric float switch;**
2. **Float and pneumatically controlled snap-action valve;**
3. **Electrode controls.**

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caused by excess grease deposits on the insulation.

Horizontal motor bearing housings are equipped with a fitting for adding grease. Excess grease is expelled through a relief plug and thus prevents overloading. Grease should be added to motors while running. It is important that motors run long enough before replacing the relief plug to permit the rotating parts to expel any excess grease. Motor manufacturers recommend that grease be added sparingly when using a pressure gun. Periodic inspection and maintenance is necessary to assure effective lubrication.

Many motors have been damaged by overgreasing. In order to minimize this trouble, some manufacturers have designed motors with pre-lubricated sealed ball bearings and bearing housings without grease fittings. The pre-lubricated ball bearings in general purpose motors have proven satisfactory. These motors can operate 24 hr. per day for five years without greasing. Thus, periodic greasing has been reduced to one grease packing job in five years and overgreasing and grease seepage into windings has been eliminated.

Motors and control equipment installed in damp locations, such as underground pump stations, have been damaged seriously by excessive condensation. The best cure seems to be the installation of a small blower of adequate capacity to change the air as often as necessary to eliminate condensation. Gravity ventilation by means of pipe openings has often proved to be inadequate. Humidity in the control box is best controlled by installation of a dehumidifier or strip heater elements in the box.

It is good practice to blow dust, dirt and other accumulations from motor windings with compressed air. The air should be free of excessive moisture and the pressure should not exceed 80 p.s.i. The frequency will depend on the location and type of motor.

Frequent starting and stopping of electric motors is detrimental. The starting current of a motor is generally several times its full load current, and will store up heat in the windings. A similar condition is caused by overloading motors. The excess heat in the windings will bake out the insulation, causing it to become dry and brittle with eventual flaking off and failure.

Where motors are installed in hot locations consideration should be given to the use of oversize motors. These motors, working below maximum capacity would be less likely to seriously heat.

Should a motor be submerged, the bearings should be immediately removed and dried to prevent them from rusting. The motor should be sent to the repair shop for a thorough cleaning, and be baked out befor it is put back into service.

For satisfactory electric motor operation, regardless of the type of motor, the following should receive a weekly check:

1. The motor shaft for freedom from oil and grease.
2. The oil level in bearings.
3. The speed and direction of rotation.
4. The commutator and brushes.
5. The tightness of all wiring connections.
6. The interiors and exteriors of the motor for freedom from moisture, oil and dirt.

Semi-annual checks should include:

1. Draining and replacement of the oil in sleeve bearings and gear box.
2. A check of the grease in ball or roller bearings.

The ball or roller bearing housings should be cleaned out and greased annually.

By using these basic maintenance checks on a regular schedule, the heart of the sewage treatment plant will be kept in a serviceable pumping condition.

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A Preventive Sewer Maintenance Program

By WILLIAM M. COLONY
Asst. Engr., Maint. and Oper. Div., Wash. Suburban San. Com., Wash., D. C.

JUST when you're getting to sleep, the night foreman calls to inform you that Mr. Jones' basement is flooded with sewage; furniture, trunks, and tools are ruined and he's ready to sue! Just when you enter a busy conference, the radio man reports a surcharged line spilling sewage into the local park—and the park officials want immediate action. Just when you finally settle down to finishing last month's reports—always when you're busiest—emergency maintenance calls interfere with your tasks, incite the public to hasty condemnation of your organization, and necessitate the expenditure of more men, more time, and more money.

Isn't it possible, somehow, to anticipate and prevent at least some of these emergency calls? With that question as a starting point, the following considers the suggested components of a plan which the Washington Suburban Sanitary Commission is now undertaking; a plan which finds the trouble before it becomes real trouble; a plan which, when fully developed, saves energy, talent, and money for more constructive work. This plan is generally known as preventive sewer maintenance.

Three Basic Phases

Preventive sewer maintenance is a planned program of inspection, servicing and repair of the sewer system. The need for such a program is obvious when the problems to be dealt with are examined. The causes behind emergency maintenance are almost as varied as they are numerous. The largest group may be listed under main-line stoppages—stoppages due to roots, sand or gravel, grease, and other material which has blocked the normal flow of a sewer. Besides relieving main-line stoppages, emergency maintenance is necessary when a surcharge of the sewer floods surrounding basements. This condition of surcharge is caused by the entrance of rain water and ground water, or by insufficient capacity of the sewer during the periods of peak flow. Preventing these problems becomes the task of a program of preventive maintenance.

Mr. Colony's article is reprinted from J.F.S. & I.W.A., Vol. 25, p. 490, with permission of the Association.

As already indicated, the three basic phases of the program are inspection, servicing, and repair. Those phases dealing with inspection and servicing are the most important, and, when treated as such, will greatly reduce the repair phase. Without question, this is the end reward of a preventive program. If this reward (reducing of repair work) is to be realized, then much time and thought must be given to planning the inspection and servicing aspects of the program.

Listing of Problems

The first objective of the maintenance engineer is to make a listing of the specific problems of his system. Such a listing can be made only after a thorough study of all available past records dealing with the maintenance of the sewer system. These records, if complete, will enable the engineer to assemble data concerning the location, type of complaint, and maintenance required to correct the trouble, as well as the frequency of occurrence. A program of periodic inspection and maintenance of the entire system should be designed to meet the conditions disclosed by this study. If past records are not available, now is the time to start assembling a complete file on every emergency sewer call received. The information contained in accurate and complete records forms the major building block for any successful preventive maintenance program.

Inspection Phase

Inspection, which is a critical examination, is the method employed by the maintenance section to determine the need for servicing sewers. A routine inspection program applied to the entire sewer system must be established to locate potential stoppages and areas subject to surcharge. An inspection of every sewer in the system would be made at least every five years. In some cases, however, records of frequent emergency maintenance may show a necessity of inspection as often as every three to six months.

In many instances, the inspection and servicing phases of the program may be carried out jointly. A good example of this is found in blocked manhole channels. When the inspection crew discovers trouble in a manhole, it can easily correct the condition without losing valuable time in delegating the responsibility to a servicing crew. The servicing crew may likewise assume some of the responsibility for inspection. When doing a routine maintenance job, inspection sould be made of the main-line sewer adjacent to the portion being serviced. The interrelationship of these crews is both logical and practical.

Planning

When planning the inspection phase, the sewer system should be divided into drainage areas. If this is done, the problem of keeping clear, accurate records of inspection will be simplified. The information to be recorded should include the date, the condition of the line, including any leaks or crushed areas, and the maintenance required. It will be advantageous to record the number of manholes inspected, cleaned, and located, and the number which will require adjustment or repair, such as raising and waterproofing. The records for such inspection are the basis for planning the work of the servicing or maintenance crew.

Inspection Crew

An effective inspection crew is composed of a foreman and three laborers and allows for one man on the street at each manhole during inspection.

Records

The foreman on the job should be supplied with two report forms; a daily record sheet on which to note all necessary information pertaining to the inspection, and a maintenance workorder sheet on which to detail the servicing which the line may need. In addition, the foreman will need a detailed map of the sewer lines in the area to be inspected, and, before leaving the job, should mark the stretches on this map to substantiate visibly the written records. This combination of daily records and maps clearly sets forth the progress of the inspection crew and provides cross-identification of the trouble spot when an emergency call is received from that area.

Locating Stoppages

When the inspection crew searches for possible main-line stoppages, it is easy to make visual inspection of

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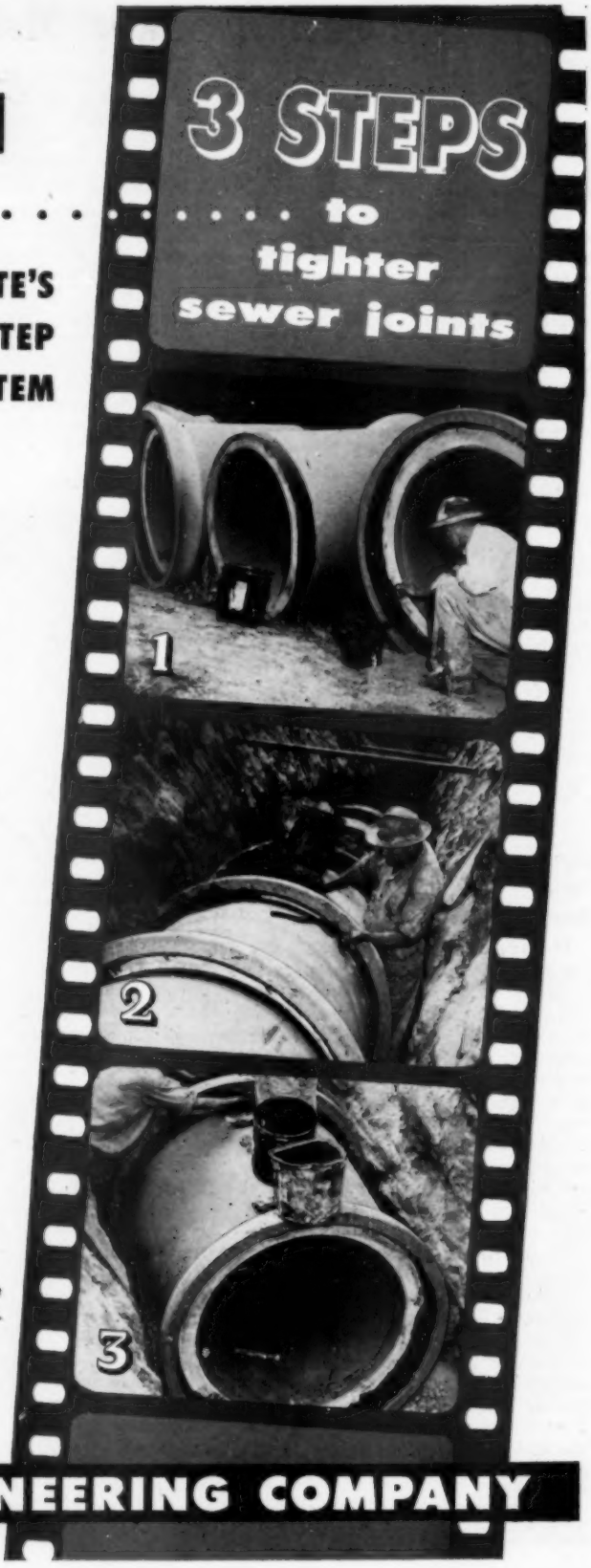

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the line by using powerful flashlights and mirrors. Although a beam of light does not always penetrate a long stretch of sewer strongly enough to disclose stoppages to the naked eye, it will reflect on a mirror held at the end of the stretch if the line is clear. Lack of such reflection reveals the presence of foreign matter in the line.

Reduction of Root Stoppages

A job which the inspection crew can handle, and which has reportedly produced excellent results, is that of treating the sewer lines with copper sulfate to discourage root growth. About 2 lb. of this chemical in crystal form, put into all terminal stretches during regular inspection, should reduce the occurrence of root growth and help to relieve a troublesome condition.

Surcharge

Another problem dealt with under the inspection phase of the preventive maintenance program is that of surcharge of the main sewers. It has been pointed out that surcharge may be due to insufficient capacity of the sewer or to the entrance of rain or surface water into the sanitary sewer. Inspection can be planned to locate and forestall the occurrence of this condition.

To anticipate and prevent surcharge caused by insufficient capacity, a program of annual flow tests of the trunk sewers in the system should be organized. Again, the sewer system can be approached on the basis of drainage areas. The trunk line within each area should be tested to determine the maximum rate of flow at the important points of sewage concentration. The rate of flow in the trunk sewer just below and just above the discharge of sewage from a large tributary area will serve as a guide for planning a relief sewer line before the need arises. Records of these flow tests may be kept on a map of the drainage area and should include, as well, the design capacity of the stretches of trunk sewer under study.

Surcharge due to the entrance of ground water or rain water may arise from several different conditions, both accidental and deliberate. The most frequent of these conditions, and, consequently, the source of many emergency calls, are open manholes in low areas, the manhole frames and covers pushed off during grading and paving operations. Routine inspection of new building developments will disclose such potential cases of surcharged lines. This inspection can be most effective during rainy periods, when it is possible to trace muddy water through the sewer lines to its source.

Where surcharge is not due to these indirect sources of rain water or ground water, it may be necessary to survey the foundation drains, downspouts, and large areaways or driveways in an area to determine the number connected to the sanitary sewer system. These surface-water connections, by introducing rain water and ground water into the sanitary sewer, may surcharge it. When the inspector with his crew locates an illegal connection, proper steps should be taken to have it eliminated. The time, effort, planning, and expense involved in such a survey are far less than that necessary to construct a relief sewer.

Constant alertness for line stoppages and for causes of surcharge are but a part of the many jobs composing routine inspection under a preventive sewer maintenance program. The problems existing in each community determine the additional phases of the inspection program. It should be obvious that getting to the source of trouble before it can become a midnight headache, by routine conscientious inspection, can greatly reduce emergency maintenance and will result in lower operating costs and more effective operation of the sewer system.

Maintenance Phase

The establishment of planned maintenance, based on past records and on inspection reports, is the second phase of any preventive maintenance program. Planned maintenance, the logical follow-up of planned inspection, can insure economy and a more efficiently operating system.

The maintenance of a sewer system should include flushing and dragging of the sewer lines, the relief of stoppages, and the repair of appurtenances. Such servicing should also be a systematic program, utilizing the inspection reports, and carried out by maintenance crews, which will vary in size and number with the amount of work to be done. When the inspection crews report line stoppages, the maintenance crews relieve those stoppages by rodding and dragging the line. Necessary work on manholes, in the way of raising, repairing or waterproofing as reported by the inspection crews should be done by the maintenance crews. When the maintenance crews have dragged roots from a clogged line, they should be instructed to treat the line with copper sulfate crystals as a precaution against further root growth in the sewer. The servicing program should also include the coverage of the recurring trouble spots throughout the sewer system.

Repair Phase

The third phase of a preventive maintenance program is repair. The repair crews should be used to relay portions of sewers which are crushed or otherwise damaged, and to replace damaged house connections. The scheduling of the work of these crews can be based on the reports of the inspection and maintenance crews and on emergency calls. In many cases, the maintenance and repair crews will be one and the same, depending upon the amount of work to be done and the number of men to do it. As has already been pointed out, if a program of preventive maintenance is carried out the repair work on the sewer system will greatly decrease as the inspection and servicing phases become more effective.

When planning a program of preventive maintenance, the interrelationship of each of the three phases is an important factor to be considered. The division of one phase from the other depends, of course, upon the situations which occur in each system and locality. It may be well to remember, however, that "a chain is only as strong as its weakest link," and although some amount of division is necessary, coordination of effort will strengthen the whole program.

Commission Program

The preventive sewer maintenance program of the Washington Suburban Sanitary Commission was started in April, 1951, when a systematic inspection of the sewer system was undertaken.

The inspection program is being carried out by one crew consisting of a foreman and three laborers. Their inspection operations follow the general outline previously suggested. Between April 1 and December 31, 1951, 118.83 mi. of sewer lines and 5,535 manholes were inspected, 173 manholes were cleaned, and 5.52 mi. of sewer lines required servicing by maintenance crews. The progress of this inspection crew has been retarded because, in years past, many manholes in this drainage area were covered over and had to be relocated and dug out before the procedure could continue.

In an effort to prevent the occurrence of root stoppages, the inspection crew has been dosing all terminal stretches of the main lines

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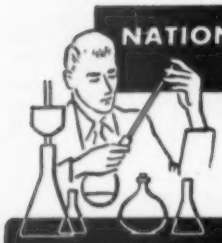

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inspected with approximately 2 lb. of copper sulfate crystals. The period during which this treatment has been used is not yet sufficient to give conclusive evidence of its effectiveness when employed as part of a long-range plan. Re-inspection of a few key stretches where root growth was evident before treatment has disclosed that the dosing was about 50 per cent effective. Further checks will be necessary before a definite conclusion as to its efficiency can be reached. The maintenance crews, as well as the inspection crew, are supplied with copper sulfate crystals and after dragging roots from a line are instructed to apply the copper sulfate treatment to discourage further root growth.

During the past year, it was necessary for the Sanitary Commsision to make a survey of a large area where surcharge consistently occurred during rainy periods. The drainage area was subjected to careful study, which included flow tests on all main-line sewers and a house-to-house check for illegal connections of drain tiles, downspouts, oversize areaways, and driveways. It was determined that the surcharge in this case was due to a combination of insufficient capacity in a portion of the main-line sewer and the entrance of ground water and rain water through regulation-size areaway drains.

In addition, 1951 saw the limited beginning of a program of annual flow tests of all trunk sewers in the sewer system. One trunk sewer was completely surveyed. In addition, the rate of flow was measured at one point on all other trunk sewers and interceptor sewers throughout the system. In order to continue and expand the program this year, plans are nearing completion for making flow tests on each trunk sewer at points of confluence with sewer lines from large contributing areas.

As for the Commission's servicing and repair organizations, a careful examination has revealed the need for improving both techniques and equipment. Only a better program of routine maintenance can prevent recurring emergency calls. With ample past records in the files to aid in the planning of such a program, it is hoped that the routine maintenance procedure will be successfully established in the near future. In conjunction with this study, an attempt is being made to evaluate the effectiveness of the present sewer cleaning equipment as compared with other equipment which may be available. Specific recommendations based on this phase of the study will be made in an attempt to improve both methods and equipment.

This program is considered as a beginning in the right direction and it is hoped to learn as it progresses. An open-minded attitude toward new ideas, and a genuine desire to improve services wherever possible, will lead eventually, it is felt, to a time when the causes of trouble can be anticipated before an emergency arises. That, in substance, will be effective preventive sewer maintenance.

Terminology in Pumping

From Hydraulic Data*

Static Head is the vertical distance in feet between the free level of the source of supply and the point of free discharge, or to the level of the free surface of the discharge water.

Total Dynamic Head, as determined on test, where Suction Lift exists, is the reading of a mercury column connected to the suction nozzle of pump, plus the reading of a pressure gauge connected to discharge nozzle of pump, plus vertical distance between point of attachment of mercury column and center of gauge, plus excess, if any, of Velocity Head of discharge over Velocity Head of suction as measured at points where the instruments are attached, plus head of water resting on mercury column, if any.

Total Dynamic Head, as determined on test, where Suction Head exists, is the reading of a gauge attached to the discharge nozzle of pump, minus the reading of gauge connected to the suction nozzle of pump, plus or minus vertical distance between centers of gauges (depending on whether suction gauge is below or above discharge gauge), plus excess, if any, of Velocity Head of discharge over Velocity Head of suction as measured at points where instruments are attached.

Total Dynamic Discharge Head, is the Total Dynamic Head minus Dynamic Suction Lift, or plus Dynamic Suction Head.

Total Dynamic Head is the vertical distance between source of supply and point of discharge when pumping the required capacity, plus Velocity Head, plus friction and entrance losses.

* From "Hydraulic Data," an Ingersoll-Rand Hand-Book.

Suction Lift

Suction Lift exists where the source of supply is below the center of pump.

Static Suction Lift is the vertical distance from the free level of source of supply to center of pump.

Dynamic Suction Lift is the vertical distance from the source of supply, when pumping required capacity, to center of pump, plus Velocity Head, plus entrance, and friction losses; but not including internal pump losses.

Dynamic Suction Lift, as determined on test, is the reading of a mercury column connected to suction nozzle of pump, plus vertical distance between point of attachment of mercury column to center of pump, plus head of water resting on mercury column, if any.

Suction Head

Suction Head (sometimes called Head on Suction), exists when source of supply is above center of pump.

Static Suction Head is the vertical distance from the free level of the source of supply to center of pump.

Dynamic Suction Head is the vertical distance from the source of supply, when pumping at required capacity, to center of pump, minus Velocity Head, minus entrance, and friction losses; but not minus internal pump losses.

Dynamic Suction Head, as determined on test, is the reading of a gauge connected to suction nozzle of pump, minus vertical distance from center of gauge to center of line pump. Suction Head, after deducting the various losses, may be a negative quantity, in which case a condition equivalent to Suction Lift will prevail.

PIPE BENDING CHART*

This chart will be found useful for determining the average radius of bend that should be given to common forms of pipe bends, numbers 1, 2, 3, and 4, as shown at the right, column E.

Also, knowing the radius of bend, the size of pipe, and the form of bend, column D gives expansion allowance of that bend.

For example a 5 in. pipe was bent to a radius of 40 inches, the bend being a common U-bend as shown by No. 2 in column E. What expansion may be allowed?

The dotted line drawn across the chart shows how the chart is used. Run a straight line through the figure 5, column A, and the 40, column B, and locate the intersection with column C. Then from the point of intersection run over to the mark in column E opposite the figure 2 and the intersection through column D gives the answer as 1.5 in. expansion allowance.

If the size of pipe were the same, 5 inches, the average radius 40 inches and the bend were a "No. 4" bend, the expansion allowance would be 3.7 inches. If the bend were a "No. 1" bend the expansion allowance would be 0.75 in.

Similarly if the expansion allowance is already known, if the form of bend is known, and if the size of pipe is known, the average radius to which the bend should be made may be determined. In other words, knowing any three of the four factors given in columns A, B, D and E the fourth or unknown factor is easily determined by following the method as explained above.

The chart is based upon these rules:

For Bend No. 1—Square the average radius of bend in inches and multiply by 0.0026 and then divide by the outside diameter of the pipe in inches.

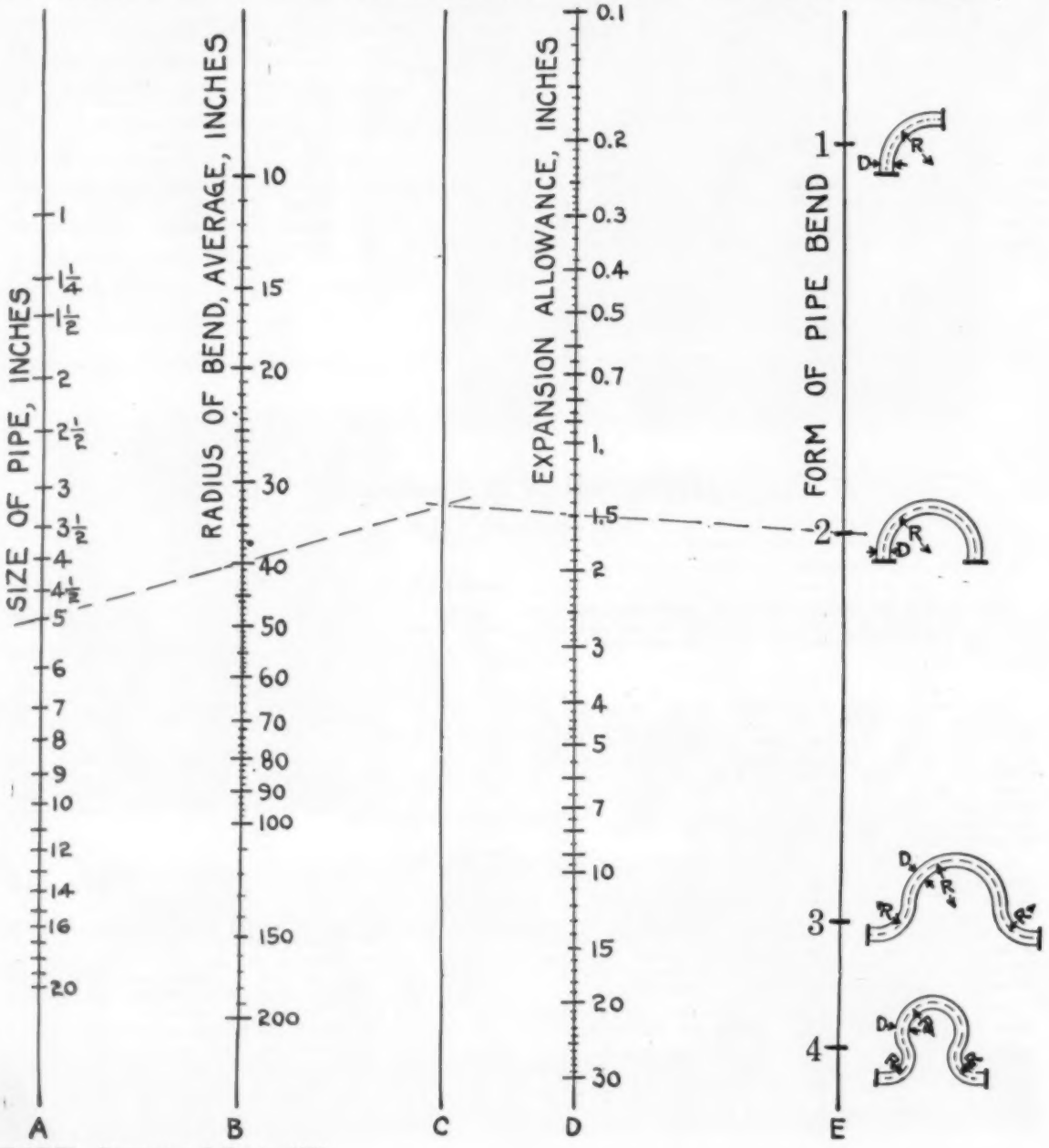
Bend No. 2—Same as No. 1 but multiply by 0.0052.

Bend No. 3—Same as No. 1 but multiply by 0.0104.

Bend No. 4—Same as No. 1 but multiply by 0.013.

In the chart all of these operations are already performed—the radii are squared, exact outside pipe diameters are employed, and the proper factors are used.

*Contributed by W. F. Schaphorst, M.E., Newark, N. J.



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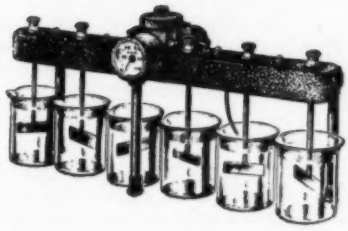

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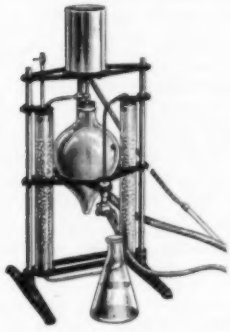

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Full operating instructions are furnished with each instrument. Additional electrical outlets are provided, along with ample storage space for cord or extra tools.

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PRIMARY TREATMENT

THE GENERALLY accepted definition of primary treatment is the removal of discrete solid particles from sewage by physical or mechanical means. There are three processes involved: Sedimentation, screening and flotation and the first of these is the most important.

Sedimentation generally takes place in two stages, utilizing a difference in specific gravity to separate different kinds of particles. The first stage is grit removal where heavy inert matter (sand, cinders etc.) is removed, the second stage removes the lighter organic settleable solids. Both stages depend on natural gravitational forces and the maintenance of velocity of flow at some definite rate. This rate must allow the particles to subside or settle rather than keeping them in suspension due to counter gravitational forces created by the relatively rapid forward motion of the liquid and its attendant swirls and mixing characteristics. High velocities will pick up relatively large and heavy particles as well as light and small particles.

Flotation involves the use of the buoyant effect on particles lighter than water. In rapidly flowing liquid these particles tend to become mixed throughout the liquid. When the velocity of flow is reduced these particles, including greases, oils, matches, etc. rise to the surface where they can be removed.

Screening involves the passage of a liquid through some physical device which contains openings of definite size which will allow passage of small particles but will catch large objects.

Grit Removal

All sewage contains grit; even where storm water is completely separated from domestic sewage. It is the function of the grit chamber to remove inert matter particularly sand, cinders, etc. If the velocity of flow of sewage is reduced to less than 1.0 ft per sec but more than 0.7 ft per sec then particles with a specific gravity of 2.6 and a size of 0.2 mm in diameter will be removed. Smaller particles will not settle.

Grit chambers are usually designed to allow from 20 to 60 seconds detention time; the shorter time being used in small plants. Provisions must be made for removing the settled grit. In smaller and older plants, duplicate chambers are used so one can be taken out of service for hand cleaning. In newer and larger plants, grit chambers are designed with mechanical equipment (flights, scrapers and buckets) for the continuous removal of the settled grit particles.

In most sewage plants, some organic matter, particularly garbage particles, earth worms, and some sewage particles will settle out with the grit. This organic matter is putrescible and might cause odors if the grit is used for fill. To remove this organic matter the grit is washed in special mechanical washers which return the organic matter to the sewage and discharge a clean grit.

The amount of grit removed depends on the particular plant and characteristics of the sewage. The volume of grit may be less than 1 cu ft per mil gal or as high as 4.5 cu ft per mil gal, particularly where a combined sewer system exists.

Screening

To protect pumps and to remove large suspended and floating solids screens are used. These are usually constructed of inclined bars spaced from ½ to 5 in. apart. Sewage passes through these bar screens at velocities of 2 to 3 ft per sec. In small plants, screens are cleaned by hand raking, but in large plants mechanical rakes are used. Basket screens have also been used as have cages for trash racks. Mechanical rakes are usually operated on a time cycle or loss of head basis.

The amount of screenings, composed of rags, paper, parts of clothing and other discarded personal effects varies with the community. Screening quantities run from 0.7 to 4.3 cu ft per mil gal. This material is wet, odorous, putrescible and generally objectionable.

Screenings removed from sewage may be buried, burned or mechanically ground and returned to the sewage, particularly where mechnical raking of the screens is practiced. Another practice is that of grinding (comminuting) the screenings beneath the surface of the flowing sewage by movable shredder blades which rotate or oscillate between the openings of a ¼ in. slotted drum or flat screen.

Few installations exist where fine screens with relatively small openings (1/32 to 3/32 in.). The quantity of solids removed on these screens amounts to 10 to 20 per cent of the suspended solids. These screens may be flat discs rotating on an inclined axis, a rotating drum, or an endless belt. The Reinsch-Wurl type is the most widely known—all types must be continually cleaned to maintain efficiency and prevent clogging.

Sedimentation

Sedimentation of sewage solids is the main function of primary treatment, but as solids are removed so too is a portion of the B.O.D. Sedimentation may take place in Imhoff tanks, or in settling tanks equipped with mechanical sludge removers.

The Imhoff tank is a two story tank, in the upper portion of which, settling takes place, while digestion of the settled solids proceeds in the lower compartment, separated by baffles from the settling compartment.

Plain settling tanks with mechanical sludge removers are termed clarifiers. They are usually fairly shallow tanks, circular, square or rectangular in which mechanical flights or scrapers push the settled sludge to some one point from which it can be transferred to digestion tanks.

In well designed clarifiers, 55 to 60 per cent of the suspended solids (or 85 to 90 per cent of the settleable solids) will be removed. At the same time approximately 30 to 35 per cent of the B.O.D. will be removed. In order to improve these removals by 15 to 20 per cent, certain aids to primary treatment may be practiced. These aids include mechanical flocculation and chemical precipitation and effluent filtration on magnetite filters.

Flotation

Some of the removals obtained in settling tanks include suspended matter with a specific gravity less than one. This matter will rise to the surface of settling tanks and can be skimmed off and removed for disposal. An aid to the flotation process air may be introduced, in fine bubbles, into the sewage to aid in floating non-settleable solids.

The material which settles out becomes raw sludge, that which floats is skimmings. The disposal of these is a subject in itself.

Screening, Grinding, and Grit Collection Equipment

by FRANK L. FLOOD

Partner, Metcalf & Eddy, Cons. Engrs., Boston, Mass.

SOME years ago Dr. Karl Imhoff made a rather extensive tour of United States and Canada inspecting sewage treatment plants. Near the end of this trip he observed to the late Mr. Harrison P. Eddy, that "in America it is fashionable to be mechanical." The trend, as observed by Dr. Imhoff, has continued and developed so that today it is not only fashionable, but practically necessary "to be mechanical" in order to take advantage of advances and developments in sewage treatment methods and processes.

Mechanization of Sewage Treatment

The mechanization of sewage treatment has not been, and is not free of problems which trouble designers, manufacturers, and operators. Initial installations of new processes and equipment are usually accompanied by difficulties necessitating changes, adjustments, and further developments. Even in the case of equipment which has been used for many years, it is desirable occasionally to evaluate experiences and to consider what lessons have been learned and what improvements can be made. It is recognized that the individual experiences may not be general. The characteristics of sewage and of the materials removed therefrom, vary so widely from time to time and from place to place that individual experience with any particular piece of equipment may range from highly satisfactory to unworkable. There is an old saying that "what is one man's food is another man's poison," and another that "the proof of the pudding is in the eating."

However, from the extensive experience with many treatment plants, some general conclusions can be derived which should be helpful to sanitary engineers in their search for the best equipment for any particular service.

The designing engineer's problem is to specify and procure equipment that will perform the desired services in a satisfactory manner for a reasonable life and involve a minimum of maintenance and operating expense. The manufacturers, without doubt, have similar aims, but they are in general in a highly competitive field, and unless the plans and specifications are clear and specific, the client may not always obtain the best equipment for the particular service. Much equipment in the sewage works field is subjected to abrasive and corrosive conditions. Equipment must be sturdy and careful attention given to choice of materials or to painting and protective coatings. Ready replacement of parts subjected to wear should be provided for. Equipment which does not satisfactorily perform the service for which it was provided causes headaches to the operators and reflects unfavorably upon the designing engineers and the manufacturers.

Sewage plant mechanization places certain responsibilities on the authority served. The necessary personnel and funds for maintenance, operation, renewals and repairs must be provided. The personnel must be capable and willing to make the equipment function in accordance with its purpose. A great deal of expensive equipment at sewage treatment plants may be seen lying idle, serving no useful purpose and deteriorating from lack of the necessary funds or the will or the know-how to make it work. Some of this idle equipment was possibly not suitable in the first place, but much of it could be operating successfully with proper care.

Racks

The operation of mechanically cleaned racks has frequently been accompanied by excessive wear on moving parts, stalling of the rakes, failure of float-operating controls to function, excessive corrosion of rakes and bars and other difficulties with resultant excessive repair and maintenance costs. Improvements and refinements in design make it possible to eliminate some of these troubles.

The difficulties encountered in the operation of large mechanically cleaned racks within the Chicago Sanitary District, have been given considerable study and analysis. The fundamental principle of design which greatly reduces the cost of maintenance and repairs as reported by L. M. Johnson[1] may be summarized as follows:

1. All parts should be designed to carry any loads required of them.
2. Motors should be selected within the maximum safe stresses of all parts.
3. Removable mild steel wearing strips should be provided on chain guides.
4. The rack mechanism should be pivoted at the floor line so that it can be lifted out of the flow in the event of a jammed rake.
5. The chains should be of heat-treated malleable iron.
6. The sprocket teeth should be chilled to produce extremely hard wearing surfaces.
7. Wide wearing shoes should be provided on the chain side bars.
8. The rake teeth should be of high bending strength and readily replaceable.
9. The rakes should be operated intermittently by time switches.

The city of New York accepted a design of mechanical rack-cleaning equipment for the Manhattan grit chambers in which the teeth entered the screen bars against the

(1) Municipal Sanitation, August 1938, page 391.

Bristol, Conn.—Bypass Rack and Chicago Pump Co. Comminutors

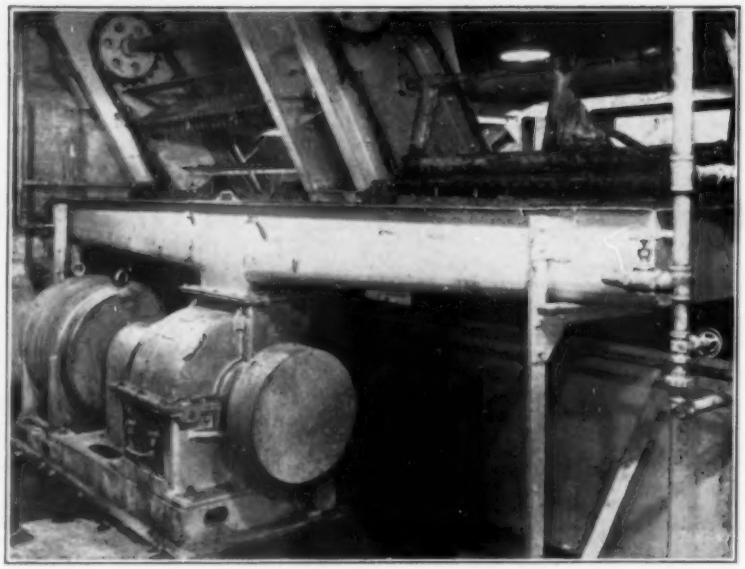
flow at the bottom. Thence the rake moves in an upward direction with the teeth protruding between the bars out on the face of the rack carrying screenings along the bars and over the top. The rakings fall off as the rakes disengage the screen bars. The results of operation of this installation at the Manhattan grit chambers were so satisfactory that the city of New York has, we believe, settled upon this type of rack for subsequent installations.

After a thorough investigation of the operation of the racks at the Manhattan grit chamber, Mr. Karl R. Kennison, Chief Engineer, Construction Division, Boston Metropolitan District Commission, adopted this type of rack with some modifications for the racks at the Nut Island plant in the Boston South Metropolitan Sewerage District. This type of rack has also been adopted for installation ahead of the main sewage pumps at the Toronto Ashbridges Bay sewage treatment plant.

For a while, it appeared that comminutors possibly would displace mechanically cleaned racks generally as the first step in treatment at sewage treatment plants for all except very small and very large plants. However, it has developed that comminutors may advantageously be preceded by grit chambers in order to reduce the cost of replacement of worn parts. Grit chambers are now almost universally required at sewage treatment plants regardless of whether or not the sewerage system is on the separate or the combined plan. In most instances, such grit chambers, particularly where equipped with mechanical grit-removal mechanisms should be preceded by coarse or medium racks. Thus it would appear that mechanically cleaned racks will still be required for many sizeable sewage treatment plants in the future.

Operation Control

Experience has indicated that the maintenance work required on racks is substantially in proportion to the hours of operation. Consequently controls have been developed to assure that the racks will be operated intermittently as needed.



Screenings Grinder—Jeffrey Mfg. Co.

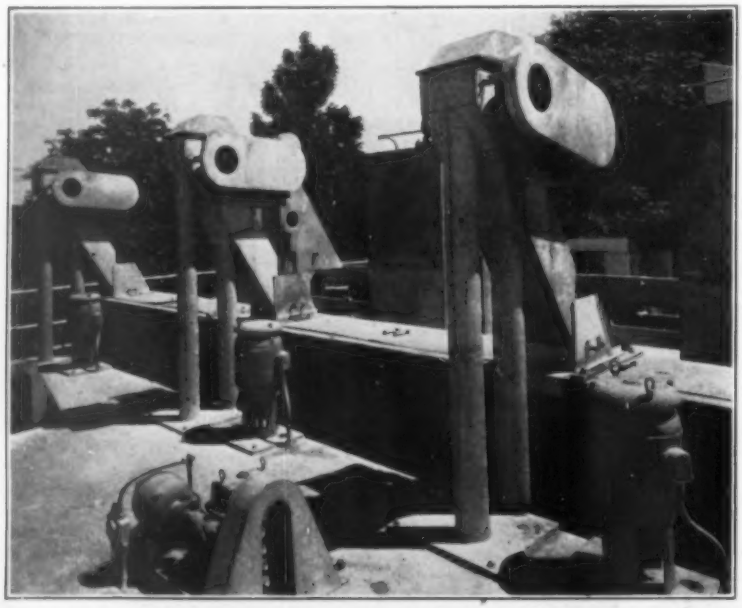
Common methods of control include time clocks and floats operating on either high-water level in part of the rack or the differential water level in front of and following the rack.

The clocks can be set to operate the racks intermittently. To eliminate possible overload on the rack between periods of operation, it is customary to set the operating time interval so as to take care of the maximum rate of accumulation of materials on the rack. Obviously, for much of the time, the rack operates more frequently than is required, resulting in unnecessary wear on the mechanism and on the controls. The clock controls involve less installation cost than float or air controls and are not subjected to the difficulties encountered with float controls.

Some authorities require that all mechanical rack operating units, normally operated by timing devices, be provided with auxiliary float controls which will set the raking mechanism in operation at predetermined high-water marks independently of the timed control.

The use of float controls has been troublesome at some installations because of solids accumulating on the floats and on suspension cords and because of their corrosion in the rack channels. The condition as regards the accumulation of materials on floats has been corrected in part at least, by providing float wells adjacent to the rack channels and connected thereto. A small quantity of flushing water creating a flow from the float wells into the rack channels can be provided to keep the float wells reasonably fresh and free of sewage solids. Corrosion can be overcome for the most part by careful selection of materials of construction.

To eliminate the difficulties encountered with float controls, a system of controls which rely on differential air pressure in pipes, immersed in the sewage in front of and behind the rack has been developed. This system is reported to give very satisfactory results. A small amount of air is necessary to activate the controls.



Decatur, Ill.—Screenings and Grit Separators Mechanisms by Walker Process Equipment Co.

Rakings

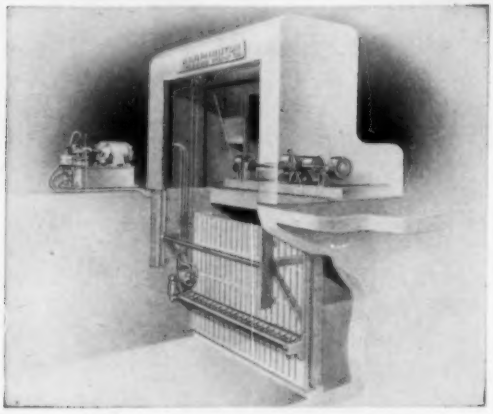
The materials removed by racks are offensive to sight and smell. It is desirable to dispose of them promptly with a minimum of handling. Much of the material removed by racks can be disposed of with the other sewage solids after grinding or comminution. Pieces of metal and sizeable chunks of wood should be removed from the rakings and disposed of separately. The common methods of preparing the solids returnable to the sewage flow, are by comminutors, grinders, and triturators. At the Los Angeles Hyperion plant, the rakings removed by the racks ahead of the Dorr detritors will be treated by an installation

Greater Flexibility in Comminution*

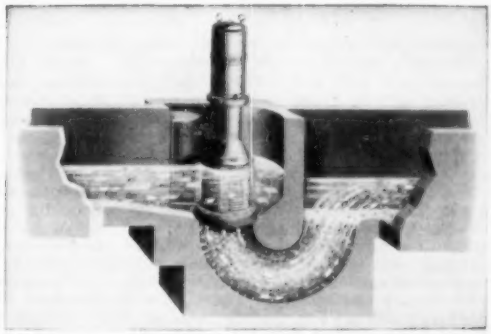
For Sewage Flows From .005 to 250 MGD Per Machine Installed In A 6" Pipe, A Basin Or A Rectangular Channel Section.

The greater flexibility and wide applicability of comminution made possible by the equipment illustrated here is the result of Chicago Pump Company's original development of comminution and the Comminutor and its 20 years of experience in over 4000 installations of exclusively successful comminution.

**Continuous screening and subsurface cutting of coarse sewage material without removal from the sewage flow, eliminating unsightly mess, nuisance and odor from screenings.*

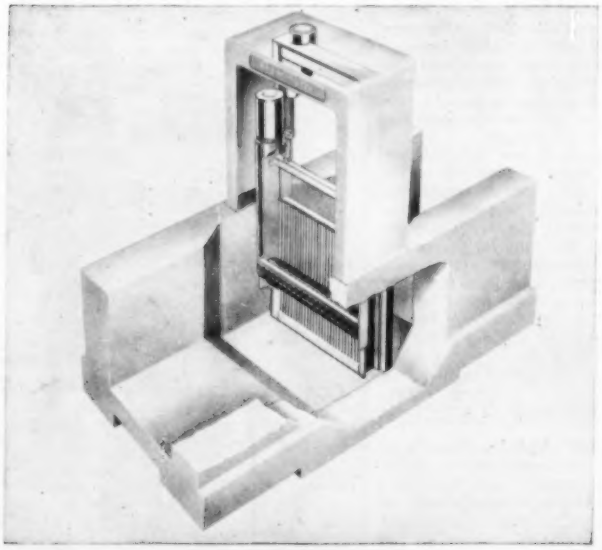


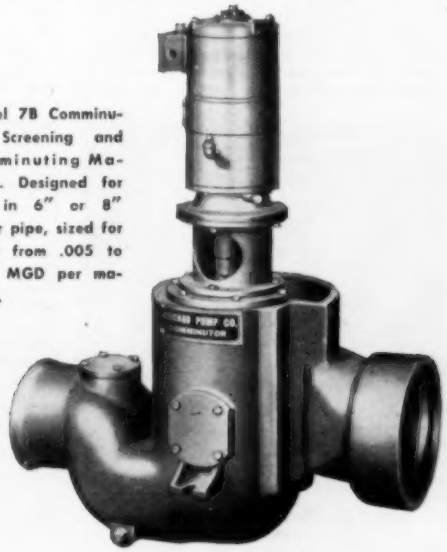
Model "A" Barminutor Screening and Comminuting Machine. Designed for use in rectangular channel sections 4 to 12 feet wide, sized for flows of 10 MGD and upwards.



The Comminutor Screening and Comminuting Machine. Designed for use in hydraulically designed feeder basin, sized for flows from .175 to 25 MGD per machine.

◀ Model "B" Barminutor Screening and Comminuting Machine. Designed for use in rectangular channel sections 1 to 3 feet wide, sized for flows from .09 to 15 MGD.





Model 7B Comminutor Screening and Comminuting Machine. Designed for use in 6" or 8" sewer pipe, sized for flows from .005 to .175 MGD per machine.

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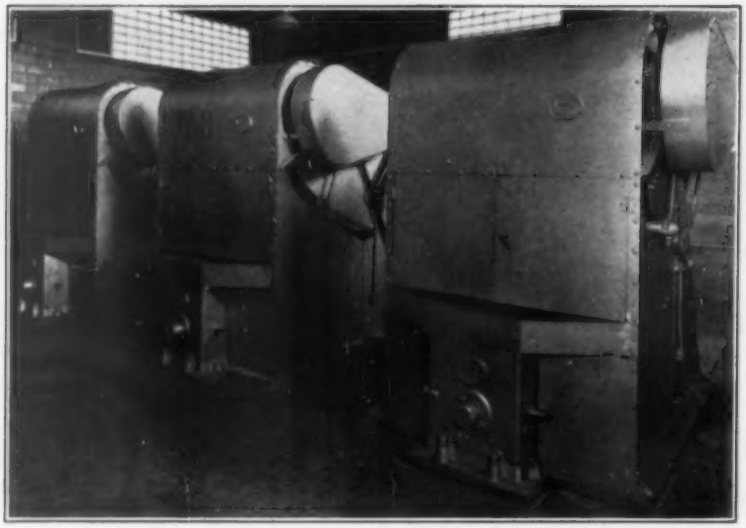
Flush Kleen ®, Scru-Peller ®, Plunger, Horizontal and Vertical Non-Clogs Water Seal Pumping Units, Samplers . . . Swing Diffusers, Stationary Diffusers, Mechanical Aerators, Combination Aerator-Clarifiers, Barminutor ®, Comminutors.



Denver, Colo.—Automatically Cleaned Bar Screens and Chain Belt Screenings Triturator

of Chicago comminutors. At the Toronto Ashbridges Bay plant, each of 6 racks will be equipped with a Jeffrey grinder. The rakings will be discharged onto a sorting table and manually fed to the grinders after materials not suitable for grinding or return to sewage flow have been removed.

At Baltimore, there are a number of installations at which the rakings at each rack discharge to a short belt conveyor. These rakings are thence carried to a separate grinder for each rack and are comminuted. Keefer reports that these installations work automatically without the necessity for manual removal of metallic and bulky materials. The evidence at several other plants is that it is not safe to rely upon automatic operation for feeding rakings to the grinders.

Comminutors

For purposes of discussion the word comminutor will be used to denote mechanisms which intercept and cut up coarse sewage solids while still immersed in the sewage flow. Until recently the Chicago Pump Co. comminutors have had competition in this field primarily from a combination of mechanically cleaned rack and grinder or triturator. The Worthington comminutor has been introduced recently and other machines for cutting up solids in the sewage flow have been, or are being, developed.

Essex Falls, N.J.—Worthington's Comminutor

While the teeth, comb and drum of the Chicago comminutor have been made of tough, wear-resisting metal, experience has shown that the wear is considerable, particularly on combined systems, unless the comminutors are preceded by grit channels. The Chicago Pump Co. has made recommendations for location of comminutor in respect to grit chambers as follows:

"Where grit chambers are required to remove heavy grit from combined sewage or gravel from street-wash, it is preferable to locate the comminutors downstream from grit chambers.

"Where it is not feasible to locate comminutors downstream from grit chambers due to structural difficulties, or to the possibility of clogging mechanical grit-removal mechanisms by uncut rags, special precaution should be taken to make the comminutor basin as accessible as possible for periodic removal of grit by the operator, to prevent undue accumulations."

Where grit chambers are required but conditions do not make it advisable to install mechanical grit-removal equipment, the comminutors usually can be conveniently located following the grit channels. Where mechanical grit-removal equipment is provided and comminutors are located ahead of the grit channels, then not only must the special precautions noted by the Chicago Pump Co. be followed but it should be recognized by the designer, operator, and owner that the necessary labor and expense must be provided to maintain reasonably sharp teeth to maintain reasonably sharp teeth and to replace worn parts as required.

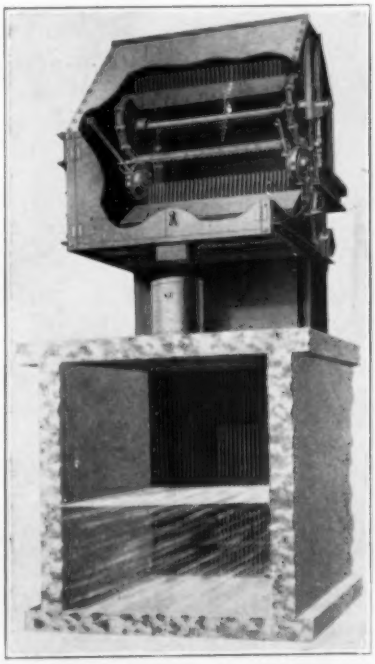
At the Nut Island plant, Boston, it was deemed advisable to install mechanically cleaned coarse bar racks ahead of the mechanically cleaned grit channels and to provide comminutors to handle the normal dry-weather flow at the effluent end of the grit channels. Supplementary mechanically cleaned fine screens were provided at the effluent end of the grit channels to treat storm flows in excess of normal maximum dry-weather rates. The screenings removed by both the coarse and fine racks will be returned to the sewage flow ahead of the comminutors. The comminutors were supplied by the Chicago Pump Co. and the rack equipment by the Jeffrey Manufacturing Co.

Grinders and Triturators

Machines for cutting up sewage solids are removed by racks and screens, out of the sewage flow, are available in two main types, the grinder as manufactured by Jeffrey and by Gruendler and the triturator as manufactured by the Chain Belt Company. The grinder is designed to grind the screenings between a high-speed rotor equipped with swing hammers, and a serrated shredder plate. The swing hammers are commonly made of high-carbon steel hardened and tempered, made easily removable and capable of being shifted end to end and side to side so as to give four wearing edges. The shredder bar assembly is also usually made of high-carbon steel, hardened and tempered, and with easily replaceable bars.

The triturator at one time consisted essentially of a toothed rotor revolving at high speed between two grates, the cutting teeth intermeshing the grate bars. As presently described, the toothed rotor operates against a perforated screen for positive extrusion of the rakings through the screen holes and simultaneous shear cutting by the teeth against the screen.

At Buffalo, N.Y., the screenings from the fine racks were passed through triturators for the first six years of operation at the Birds Island plant. For the past four years, however, the screenings have been disposed of by burial after the operators reached the conclusion that handling, transporting and burial presented less of a problem than grinding. At this plant, it was found that the screenings contained so much hard material, such as bits of stone and pieces of metal and wood, that the effective life of the teeth was very short. New or resharpened teeth became dull in a very few hours of operation and then did not properly shred the material passed through them. This gave a great deal of trouble further along because of the condition in which the rags were left.



Thru-Clean Bar Screen by Link-Belt Co.

Both grinders and triturators have been in successful operation for at least ten years in moderate-sized sewage treatment plants with which we have been associated as engineers.

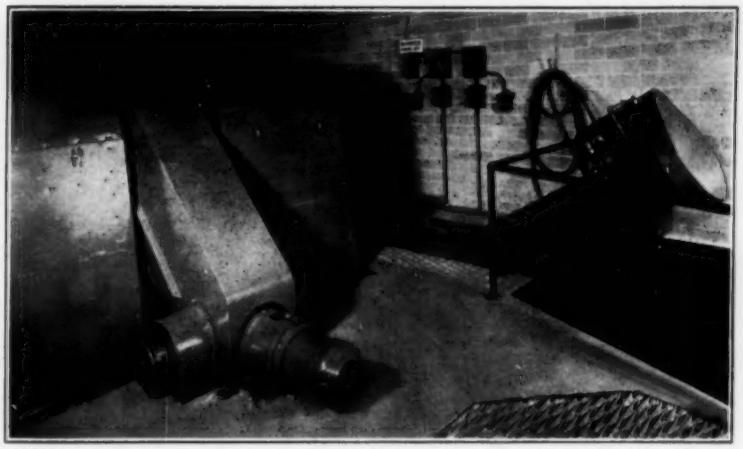
Balls of material have been known to accumulate on the grinder shredder plate which cause trouble later on in the plant as they finally drop off. It is believed advisable, when feasible, to return the discharge from grinders and triturators to the sewage ahead of the racks.

Other Operating Information

As typical examples of operating installations the following paragraphs set forth information on three plants.

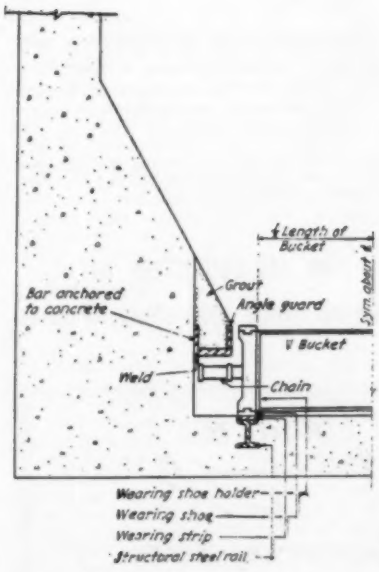
A mechanically cleaned bar rack and grinder as supplied by the Jeffrey Mfg. Co. was installed at the North Adams, Mass., sewage treatment plant during 1936 and has completed 13 years of operation. The maintenance work on the individual parts as reported by Paul Fleming, Plant Supt., has been very small. The rake jams occasionally if the chains become uneven, but this has not been considered serious by the operators. Automatic operation of the grinders is not employed as it has been learned from experience that large masses of rakings will clog the grinder necessitating opening it up and cleaning it out. New rotor weights have been placed on the hammers three times in 13 years. This involves only a moderate expense.

A mechanically cleaned bar rack and triturator as supplied by the Chain Belt Co. and installed at the Tonawanda, N.Y., sewage treatment plant was placed in operation in 1940. The operating experience has been reported to the author by James J. Kampas, Chief Operator, and Benjamin Hinkey, City Engr. The rake is operated either by time clock or manual control. Large objects have at times jammed the rakes at the bottom of the rack necessitating dewatering the rack channel for their removal. It has been found necessary to replace the rakes, bars, lower sprockets, and scraper arms because of wear and tear. The triturator teeth are periodically sharpened and need to be replaced on the average after two to three years of service.



Sheboygan, Wisc.—Two Rex Grit Collectors and Rex Separate Grit Washer

Inquiry has also been made as to the operation of the rack equipment at the Bloomington and Normal Sanitary District. In the January 1940 issue of Water Works and Sewerage the satisfactory operation of the Chain Belt mechanically cleaned bar rack and triturator was described by Orie J. Hendryx, then Supt. of the Bloomington and Normal Sanitary District. Mr. George L. Hall, the present superintendent of this plant, reports to the author that the original equipment is still in use except that the chain was replaced in 1948. Equipment to replace the lower boot section including sprockets and pins is at hand to make this replacement when it becomes necessary. Mr. Hall reports that the operation of the equipment during the past eight years has been satisfactory.



Typical section of corner of grit channel

2—Grit Chambers

The more prominent of the various means that have been used for the mechanical removal of grit from grit chambers at sewage treatment plants may be summarized as follows:

Scraper blades or flight conveyors
Bucket conveyors
Inclined flight conveyors
Inclined screw conveyors
Vertical bucket elevators
Belt conveyors
Grab buckets
Grit eductors and ejectors

The above equipment may be used separately or in various combinations. The grit may be collected at the influent end of channels by means of flight conveyors, scraper blades, or horizontal bucket conveyors, and then elevated by inclined flight conveyors, inclined screw conveyors, or by vertical bucket elevators or be pumped by eductors or ejectors. The grit as elevated from the individual channels may be then transported by means of flights, buckets and screw or belt conveyors to further treatment units or to points of disposal.

It is difficult to obtain manufacturers' agreement on recommendations for grit channel equipment. Each manufacturer has his own ideas as to what should be provided. These ideas are influenced, in part at least, by one of several reasons. Generally, the manufacturer desires to incorporate methods and equipment which: (1) he has tried and perfected to a reasonable working basis, (2) has become more or less standardized with the company, (3) he holds patents on, (4) will avoid infringement of patents held by others, or (5) will enable the manufacturer to compete on a favorable basis for the work of furnishing the equipment.

Severe Wear Encountered

The scraper blades and flights used for conveyors and elevators, the bucket conveyors and elevators or the inclined screen conveyors and elevators, all require moving equipment immersed or partially immersed in the sewage and grit. Due to the abrasive character of the materials handled and other operating conditions, grit chamber equipment of this type is subjected to a high rate of wear. In its design, therefore, the emphasis should be placed upon rugged, durable construction, with ready means for replacement of worn parts.

The operation of equipment in the grit chambers at Buffalo has been described by Johnson.[4] In these chambers the grit is collected by flights riding on rails embedded in the concrete floor. The shoes on the flights wore out rapidly and when replaced by shoes of highly resistant metal the soft steel guide rails wore down and had to be renewed. A design was developed in which the wear was taken by an easily replaceable wearing rail.

Tail bearing assemblies at the ends of the inclined screen conveyors were cut to pieces within a short time by the passage of fine grit particles into the bearing. The life of this bearing was prolonged by a combination of steel, rubber and paper gaskets with an adjustable packing gland which has excluded for a longer term and to a greater extent the working of abrasive material back into the bearing.

Aer-Degritter and Comminutor installation, Mayfield, Kentucky. Design flow 1.5 M.G.D. Russell, Axon & Associates, Engineers.

AER-DEGRITTER

Air Controlled Settling Velocities Independent of Flow

The Aer-Degritter* removes grit and sand from sewage through the use of air to effect a controlled velocity of the sewage in the grit tank. The method provides a quiescent zone beneath the air diffusion media to effect a selective deposition of clean grit without organics. There is no need for separate grit washing tanks. Washing and deposition are effected in a single tank.

The principle of air controlled velocities was first demonstrated in sewage treatment plants designed by the office of Charles H. Hurd, Consulting Engineer. The Hurd method, using diffuser plates located behind the hopper, was an improvement over the then practiced means of controlling grit tank velocities. The Aer-Degritter* using diffuser tubes located directly above the hopper is, in turn, an improvement on the Hurd method.

POINTS OF SUPERIORITY OF THE AER-DEGRITTER*

1. Relative location of grit hopper and air diffusers. In the Aer-Degritter* the diffusers are elevated above the tank floor and the grit hopper is directly beneath the air diffusers. This permits greater flexibility of control of tank bottom velocities regardless of volume of sewage flow. It is these bottom velocities that control the deposition of clean grit and fine sand without also depositing organic material. Tests made on grit removed by Aer-Degritters* have consistently shown less than 0.05% putrescibles.

2. The equipment used to introduce air to the sewage. The use of Swing Diffusers and Precision Diffuser Tubes permits easy access to the grit hopper and cleaning of the diffuser media without taking the tank out of service.

*The application of the equipment, as well as the equipment itself is covered by U.S. Patents No. 2,532,457, No. 2,144,385, No. 2,328,655 and No. 2,555,201.

OVER 140 AER-DEGRITTERS IN* OPERATION IN LARGE AND SMALL PLANTS

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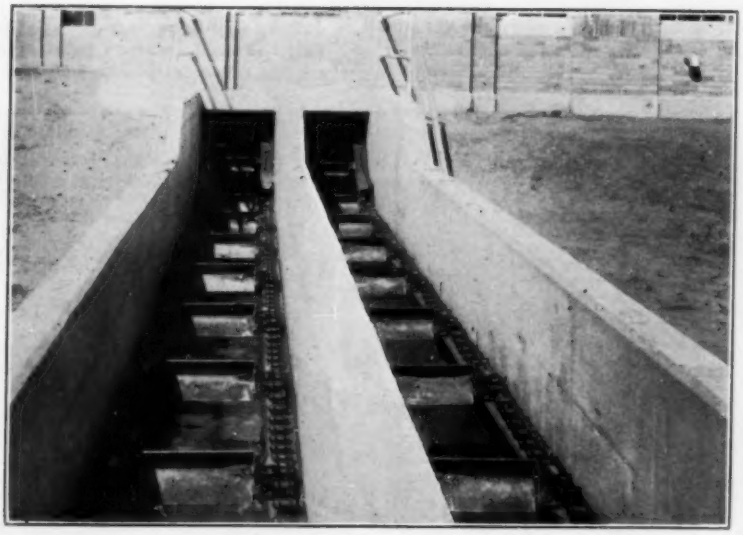
Flush Kleen ®, Scru-Peller ®, Plunger, Horizontal and Vertical Non-Clogs Water Seal Pumping Units, Samplers . . . Swing Diffusers, Stationary Diffusers, Mechanical Aerators, Combination Aerator-Clarifiers, Barminutor ®, Comminutors.

Write to Department G for Engineering Data



Rock Island, Ill.—Jeffrey Grit Collectors

The grit chamber equipment at the District of Columbia Blue Plains plant was originally supplied with inclined screw conveyors with thrust bearings near the bottom of the grit hoppers. Because of continual submergence in grit, these bearings lasted only a very short time. To overcome this difficulty, the bearings were replaced by ball thrust bearings above the sewage level. In addition to eliminating the frequent failure of the underwater bearings, much smoother operation of these units resulted.

The grit chamber equipment at the Toronto Ashbridges Bay plant includes bucket conveyors and elevators on parallel endless strands of chain. The rails in the concrete channel bottom have readily replaceable wearing plates. The attachments supporting the buckets include removable wearing shoes of gray cast iron to ride on the rails imbedded in the channel bottom and on the angles supporting the return flight. The return angle rails and the removable wearing shoes are of ½ in. thickness.

In an effort to reduce the wear on chains, attachments, shoes and rails, the Chain Belt Co. has devised and advocated construction as shown in the accompanying figure. This provides in effect a chain guard which prevents grit from falling directly onto or compacting directly upon the conveyor chain, thus reducing the abrasive action of the grit on the chain, its supporting attachments, and the guide rail.

Overload and Shear Pins

In the past, grit-collector equipment has been protected from overload largely by the use of shear pins. The objection to the use of shear pins has been that as these break under overload the operators have been inclined to replace them with stronger pins until a chain, sprocket, shaft or other element is seriously damaged or broken requiring major repairs. The development and use of stalling torque motors on grit chamber equipment so as to eliminate the use of shear pins was discouraged during the war and has been somewhat neglected since. Recently adjustable overload release devices have been advanced which are designed to mechanically disengage the grit collectors from the motor when overloads are encountered.

In order to secure truly competitive bids on grit chamber equipment, it may be necessary to provide detailed specifications and reasonably detailed plans.

The hunting tooth or extended life sprocket of alloy cast iron with a nickel content of 1.00 to 1.25 percent and a chromium content of 0.45 to 0.65 percent with teeth chilled to give a hardened wearing surface should give reasonable life.

Velocity Control

In many grit channels the effective removal of grit is dependent upon control of velocity. Various devices have been used to effect control so that a velocity in the vicinity of 1 ft. per second is maintained throughout the range of sewage flow from minimum to maximum for which the channel is designed. This may be accomplished by properly designed proportional weirs for rectangular channels which increase the depth of flow in direct ratio to the increase in rate of flow. This plan may require considerable loss of head at the grit channel during maximum rates of flow.

It is common practice at present to provide control sections following grit channels, such as the Parshall flume or the Camp regulator as manufactured by American Well Works,[3] and to design the cross-section of the grit channel to suit the backwater conditions created by the control section. Where the Parshall flume serves as the flow level control section for the grit channels, it is also usually adapted for measurement of sewage flow.[4] It is convenient to provide a flow indicator at the flume and adjacent to the grit channels so that the experienced operator can readily determine the number of channels which it is advisable to have in operation.

Grit Conveyors

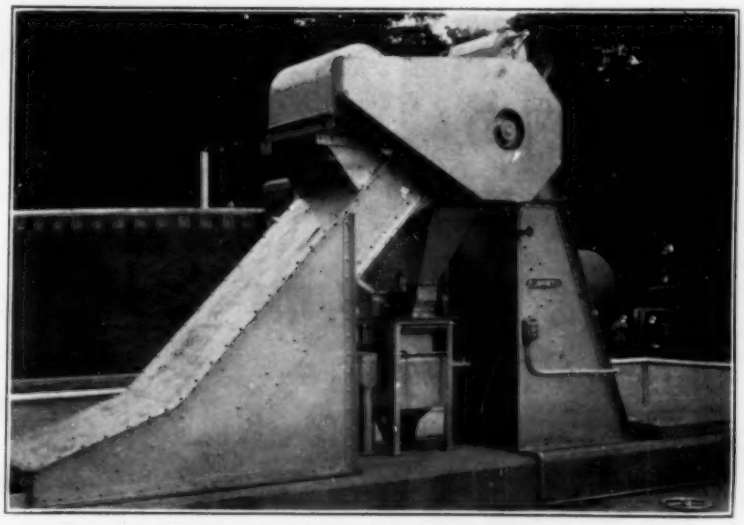
Belt conveyors for horizontal transportation of grit from multiple grit channels to grit-washing, storage, and disposal points, appear to operate with less maintenance costs than scraper, bucket, or spiral conveyors.

Pneumatic grit ejectors as made by Krajewoski-Pesant Manufacturing Co. are provided at the Tallmans Island plant in New York for discharging grit from the grit house to storage tanks in an adjacent building.

Fuller[4] reports successful operation with a pneumatic grit washer and ejector at Olean, New York. He states that formerly six man-days were required to remove the grit by hand, chain hoist, and truck, followed by burial, whereas the air-lift system washes the grit and disposes of it in thirty minutes. The washed grit is discharged to the Allegheny River. It is noteworthy that the air-lifted grit discharges through a 6-in. pipeline as compared with 3-in. and smaller pipelines used in connection with some grit eductors and jet pumps.

Grit Cleaning

The purpose of providing grit cleaning equipment is to remove the organic and putrescible materials settling with the grit so that the resultant product will be rela-

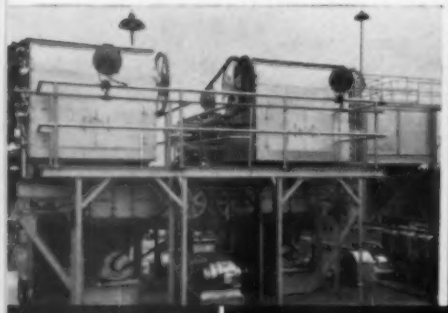


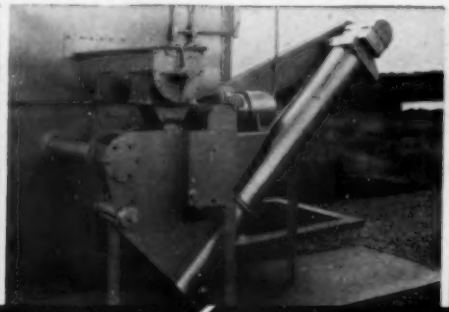
Wisconsin Rapids, Wisc.—Jeffrey Jigrit and Collector

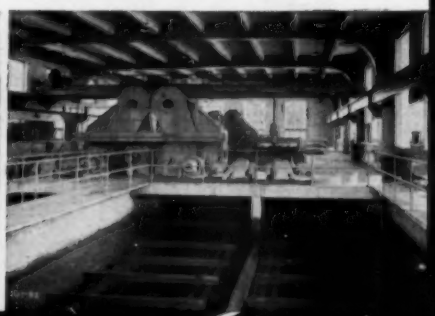
Jeffrey Screens meet every requirement . . . Jeffrey Grinders provide sanitary disposal of screenings.

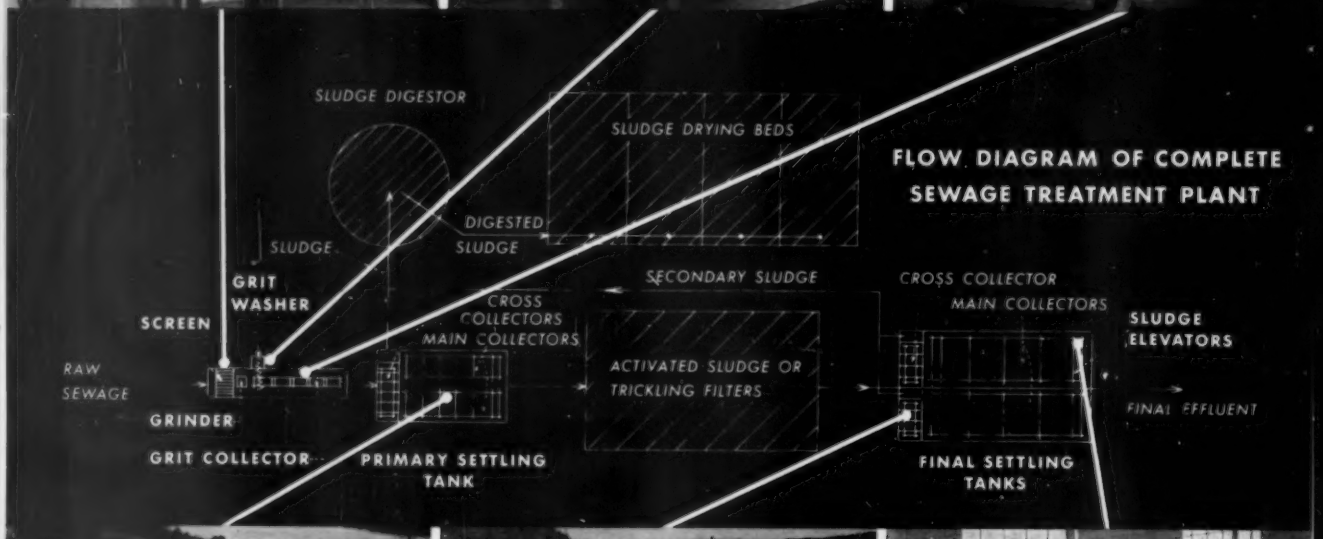
Jeffrey Grit Washers produce grit that's suitable for use as fill without any further treatment.

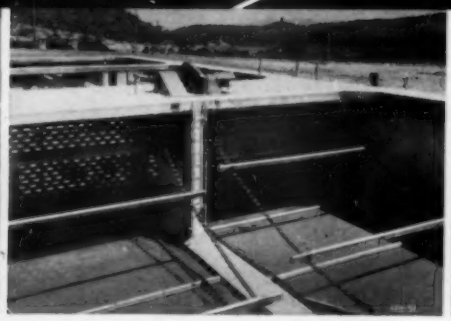
Jeffrey Grit Collectors are selected to suit the accumulation rates at each sewage treatment plant.

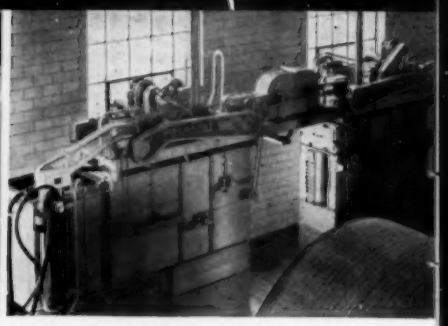












Jeffrey Primary and Final Settling Tanks give stable flow conditions, assuring maximum sedimentation.

Jeffrey Collectors and Drive Units are long lived and inexpensive to maintain.

Jeffrey Sludge Elevators are sturdily constructed of materials selected to resist wear and corrosion.

let JEFFREY **MECHANIZE** your sewage treatment plant!

Hundreds of treatment plants are Jeffrey equipped —servicing villages of 1500 to cities of several million. This wide experience enables Jeffrey Sanitary Engineers to offer you sound advice on your sewage disposal problems. This service is described in Catalog 833-A. The Jeffrey Manufacturing Company, Columbus 16, Ohio.

JEFFREY

CONVEYING • PROCESSING • MINING EQUIPMENT
TRANSMISSION MACHINERY • CONTRACT MANUFACTURING

tively free from objectionable characteristics, particularly odor.

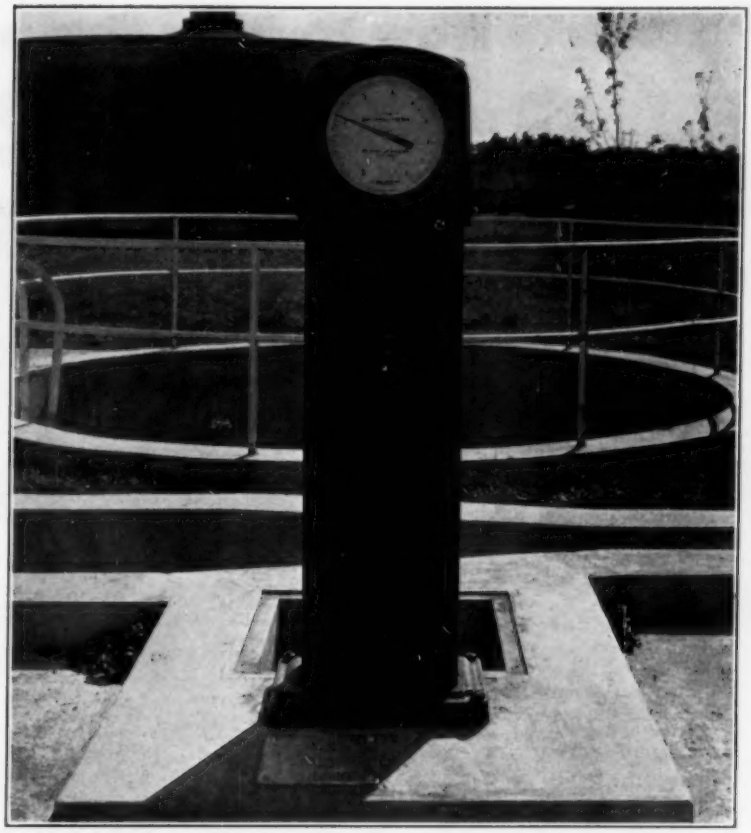
A relatively clean grit can be obtained if the grit disposal conditions make this necessary. Under ordinary conditions of grit disposal in spoil areas, grit of satisfactory quality may be obtained by one of several different processes. In many plants, satisfactory results have been obtained by returning the grit as first removed, back to the inlet of the grit channels at the surface of the flow. The grit is thus washed in the sewage flow and after washing is again removed by the equipment provided therefor.

The Dorr detritor has been described and operating data from 41 installations has been reported by Kivell and Lund.[8] The detritor grit chamber is square in plan. The grit is collected at one side of the chamber by means of scraper blades on revolving arms, and is then elevated by means of reciprocating scraper blades working on an inclined plane. The reciprocating rakes create turbulence and a back and fill motion as the grit is carried up the slope, which tend to throw light organic materials into suspension.

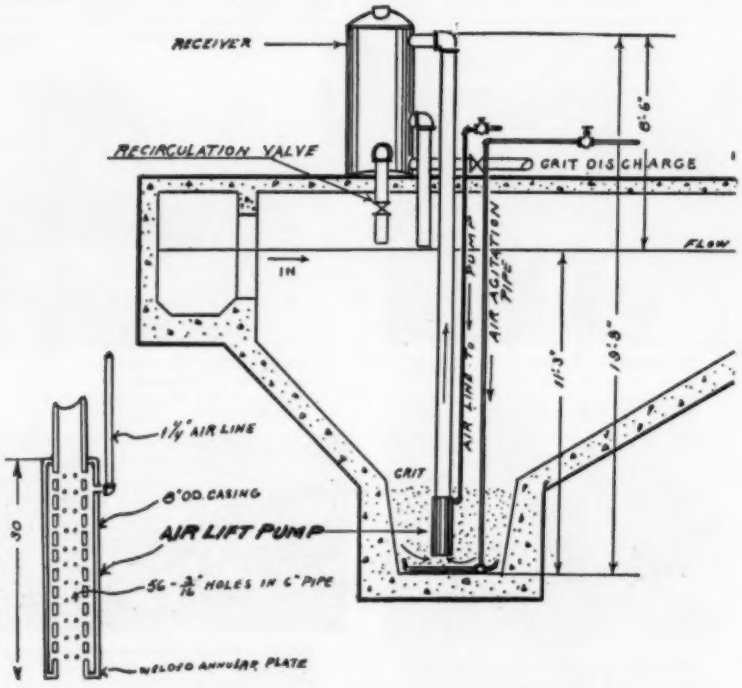
Other manufacturers recommend the use of an inclined screw conveyor for removing the grit directly from the grit channels. The Link Belt equipment at Peoria and the Chain Belt equipment at the District of Columbia are of this type.

In some plants the grit as removed from the grit channels is deposited in separate grit-washing channels equipped with either inclined screw conveyors or reciprocating rakes.

The "Jigrit" washer as manufactured by Jeffrey has been installed at several New York City plants and has been selected for the Nut Island plant in Boston and the Ashbridges Bay plant in Toronto. The grit as removed from the grit channels is discharged to the "Jigrit" for separation by stratification and washing of adhering organic solids. The principal wearing part in the washer is the diaphragm which in some instances has required replacement on the average of once each year. The early tests of this equipment at the Indianapolis plant have been reported by Nichols and Tolman.[9]



Bristol, Conn.—Builders-Providence Parshall Flume Register and Recorder



Olean, N.Y.—Details of pneumatic grit washer and ejector—After Fuller

Grit Storage

In mechanically-cleaned grit chambers of conventional design in which the grit is moved by means of flights, buckets or screw conveyors, the equipment must be operated as frequently as is required to prevent it from becoming buried in grit to the extent that it will not start up. Intermittent operation may be practical during dry weather, but frequently continuous operation is necessary during periods of storm flow. In many plants it is necessary to provide some form of grit storage facilities to act as a reservoir between the operations of grit removal and the filling of trucks to haul it away for disposal. Elevated storage bins have been quite commonly used. It has frequently been found that the grit compacts in the conical hopper bottoms of these bins above the grit draw-off gate, making it difficult to load the trucks. It has been found that air introduced to the grit bin just above the gate makes it possible for the grit to flow so that it can be drawn off readily and smoothly.

Particular attention should be given to the design and construction of gates beneath the storage bins. In several plants

How to plan sewage, water and FOR THE

Specify LINK-BELT equipment . . . lasting, efficient, flexible

IN many cities, growing populations have required expandability to be designed into water and sewage treatment systems. Increasing production, plus anti-pollution measures, creates much the same situation in industrial waste treatment. The broad range of long-life Link-Belt sanitary engineering equipment is helping to meet these requirements—permitting design flexibility that provides for easy enlargement with minimum changeover.

Our sanitary specialists will work with your own engineers, chemists and consultants. For more details, call your nearest Link-Belt office.

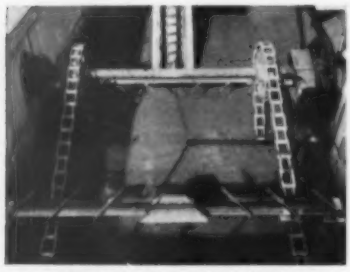
OTHER LINK-BELT PRODUCTS INCLUDE: Scum breakers, air diffuser units, non-clogging spray nozzles, traveling water intake screens, Roto-Louvre sludge dryers, chemical handling machinery, car spotters and haulage systems . . . Catalogs sent on request.

This Eastern sewage plant had to provide practical sewage treatment for a population of 870,000—yet be able to serve an estimated 1,200,000 expected by 1970. Link-Belt supplied screens, grit collectors and sludge collectors to handle 136 mgd.

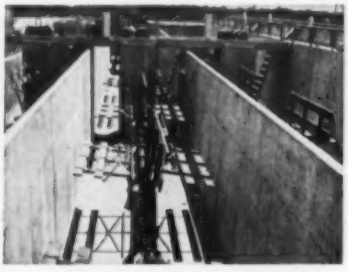
LINK-BELT

SANITARY ENGINEERING EQUIPMENT

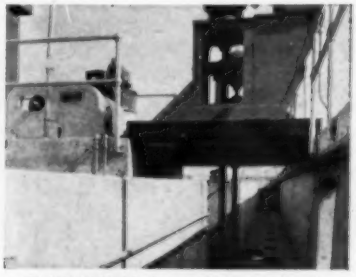
LINK-BELT COMPANY: Executive Offices, Prudential Plaza, Chicago 1. To Serve Industry There Are Link-Belt Plants and Sales Offices in All Principal Cities. Export Office, New York 7; Canada, Scarboro (Toronto 13); Australia, Marrickville, N.S.W.; South Africa, Springs. Representatives Throughout the World. 14,082



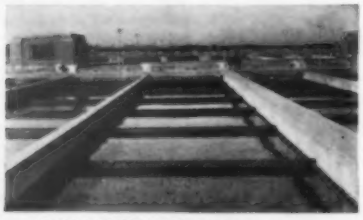
GRIT COLLECTORS AND WASHERS effectively collect and wash settled grit and separate it from putrescible organic matter before removing.



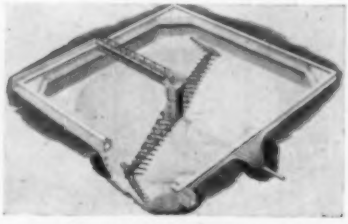
STRAIGHTLINE MIXERS for rectangular tanks, cross or transverse horizontal flow. Degree of mixing can be varied to produce maximum size floc.



FLASH MIXERS thoroughly mix chemicals prior to flocculation . . . prepare chemicals and water for immediate flocculation.



STRAIGHTLINE COLLECTORS for rectangular settling tanks feature peak-cap bearings, pivoted flights and Straightline action for top efficiency.

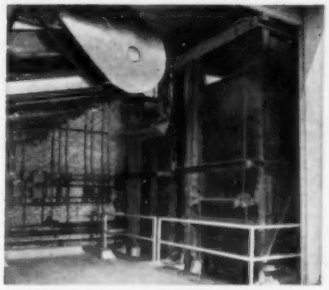


CIRCULINE COLLECTORS for square or round tanks provide positive sludge and scum removal in shortest time without septicity.

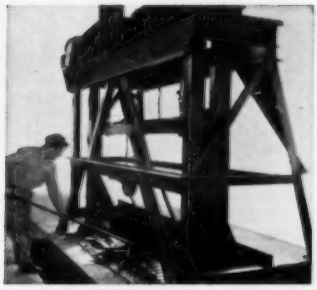
BIO-FILTRATION SYSTEMS utilize high-rate shallow filters . . . recirculation of effluent from filter to primary settling tanks . . . recirculation from final tank to filter. Single- or two-stage.

waste treatment facilities
YEARS AHEAD

THRU-CLEAN BAR SCREENS remove large floating particles from large volumes of water, thus protect other equipment from damage.

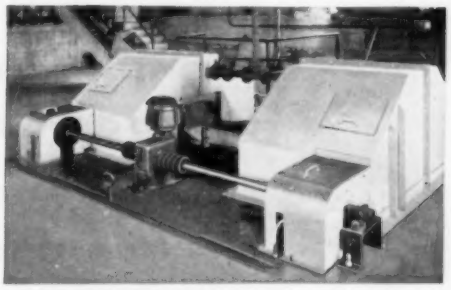


STRAIGHTLINE BAR SCREENS can't jam, assure constant, automatic screenings removal under extreme conditions.

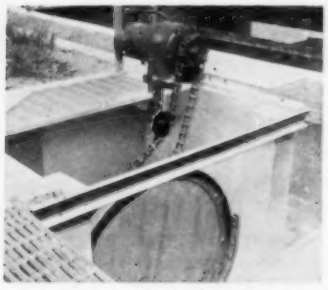


TRASH SCREENS are operated intermittently for removing large floating debris to protect water screens and other equipment from damage.

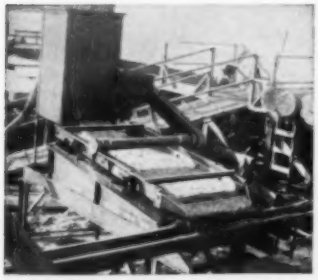
TRITOR SCREENS remove both grit and screenings with one mechanism. Recommended for small sewage plants.



ROTARY DRUM SCREENS remove large quantities of fine solids from surface water intakes, settling tank effluents and industrial wastes. Extremely low maintenance requirements.

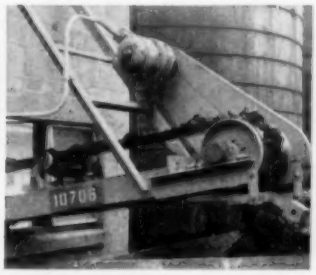


REVOLVING DISC SCREENS offer low-cost separation of very fine solids . . . minimum loss of head in installations where water depth is relatively constant.

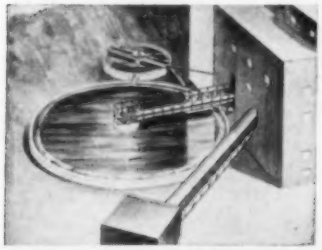


LIQUID VIBRATING SCREENS are widely used for removing fine solids from liquids. Several sizes, with fine cloth.

SCREW CONVEYORS AND BUCKET ELEVATORS meet the need for efficient handling of lime, alum and other chemicals where space is limited.

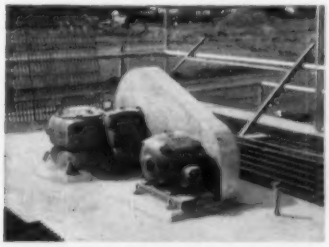


BELT CONVEYORS are one of various types of conveyors available for handling bulk or bagged chemicals, sludge filter cake or sludge from drying beds.



THICKENERS AND CLARIFIERS are made in several types and various sizes, including rake and flight types, for high efficiency and low cost operation.

CHAINS AND SPROCKETS as on this mill scale collector or for any conveying or power transmission need can be found in Link-Belt's complete line.



POWER TRANSMISSION PRODUCTS include enclosed gear, fluid and variable speed drives; bearings; chain drives as used on this vertical Straightline mixer.

Better Grit Conditioning

Rex Pioneering of the recirculation principle in grit chambers led the way to cleaner grit . . . more efficient removal.

Better Sludge Removal

Development of the Rex Tow-Bro Sludge Remover with its unique, gentle, suction-type action assured better removal of light, flocculent sludge.

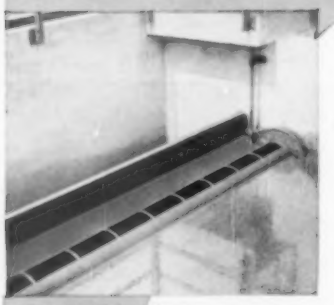
Better Settling

Introduction of the Rex Verti-Flo® Clarifier made possible improved settling . . . increased capacities . . . important cost savings.

leader

in a quarter century of progress

REX® **sewage and waste treatment equipment**



Better Skimming

Development of Rex Full-Width Skimming Equipment, manual and automatic, made possible more efficient removal of floatable material.

Continuous research, product development and improvement have long been guiding principles of CHAIN Belt Company. The important developments illustrated above are but a few of the contributions CHAIN Belt has made to more efficient plant performance . . . a quarter century of sanitation progress. Such mechanical features as Z-Metal chains, self-aligning bearings, centralized wearing shoes, split head-shaft sprockets have meant much in longer life, lower operating and maintenance costs and better operation to plant operators the world over.

Your Rex Field Sales Engineer will be happy to give you the complete details. Or, write CHAIN Belt Company, 4610 W. Greenfield Ave., Milwaukee 1, Wis.

Better Solids Removal

Development of Rex Front Cleaning Bar Screens assured more efficient removal of solids.

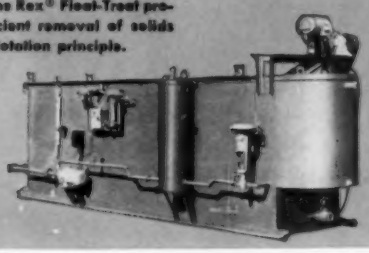
CHAIN BELT COMPANY
MILWAUKEE 1, WISCONSIN

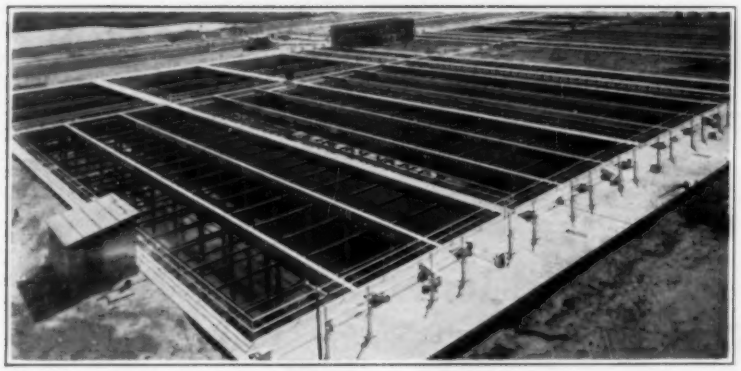
Better Grinding

The Rex Triturator was an important contribution to improved operations with its 2,000,000 blade cuts per minute.

Better Flotation

Introduction of the Rex® Float-Treat provided more efficient removal of solids through an air flotation principle.





Minneapolis-St. Paul—Chain Belt Rex Sludge Collectors and Automatic Skimmers

the gates installed have been difficult to operate manually and various expedients have been used, including extension of lever arms and, at one plant, by the addition of a block and tackle.

Provision should also be made for collecting and disposal of drainage from grit storage hoppers. A device consisting of a pan beneath the grit draw-off gate supported by a swiveled pipe arm which can be swung out of the way during truck-loading periods, has worked successfully.

Aerated Grit Channels

The accumulation of grit in aeration tanks, not preceded by sedimentation tanks or adequate grit chambers, has been observed for some time, particularly when the tanks have been equipped with elevated diffusers. Air has also been used in grit separation tanks in an attempt to separate out light organic materials. However, so far as we are informed, it is only recently that an attempt has been made to develop a rational basis of design for spiral flow aerated grit-separation tanks.

The apparent advantages of the aerated grit chamber as compared with other types are: (1) complicated control of velocity is not required, (2) variations of rate of flow through the chambers are of little importance, (3) the grit as removed does not require further washing for removal of organic materials, and (4) the grit can be allowed to accumulate in the grit hoppers and removed for disposal as may be convenient.

The most practical method of removal of grit from aerated grit channels will depend in part upon the size of the units. The Chicago Pump Co. has been interested in the development of the aerated grit chamber and its possible use in conjunction with pre-aeration tanks, possibly because of the use of swing diffusers in such tanks. This company has advocated the use of multiple hoppers under the diffuser system in which to collect the grit and its removal by means of jet pumps. The water used for pumping the sand would normally be plant effluent, pumped by a separate high-head pump. The grit-water mixture may be pumped to decanting tanks or grit drainage sand beds.

There is a lack of experience with this type of grit ejector so that it is not known whether it will work with satisfaction under any and all conditions. The foreseeable difficulty with the relatively small ejector nozzle and pipe is clogging with rags or other coarse materials removed with the grit.

The large scale aerated grit chamber installed at the Columbus, Ohio, sewage treatment plant has been described by Grant.[7] At this plant the grit is picked up from tank-bottom hoppers by a one-half-yard clam bucket suspended from a bridge crane with a 60-ft. span over the tanks. The bucket empties into dump trucks.

The aerated grit chambers at Columbus replace chambers of more conventional design. Except for the clam bucket there are no moving parts in the sewage so that wear and tear of equipment is reduced to a minimum.

It appears that aerated grit chambers may be used quite extensively in future designs. Their use in conjunction with pre-aeration tanks will be watched with interest. It appears desirable, for any sizable units, to provide fine mechanically-cleaned racks ahead of the aerated grit channels so as to reduce to a minimum the quantity of materials which could wrap around and collect on the diffuser tubes and air piping.

Incineration of Grit

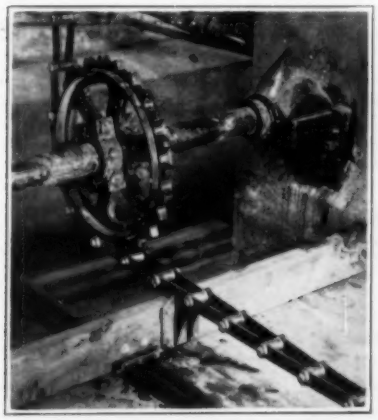
The grit at the Buffalo sewage treatment plant was incinerated with the sewage sludge from September 1940 through April, 1941. It is reported that it was found possible to burn as high as 50 percent grit with 50 percent sludge for extended periods and occasionally for short periods to burn grit alone. However since April 1941 the grit which has about 40 percent volatile material has not been burned and has been transported to a disposal site without reported objection. According to Johnson[1] incinerating the grit caused excessive wear to equipment and caused plugging and clinkering in the ash removal system.

The grit removed at the Detroit sewage treatment plant has been incinerated in multiple hearth furnaces with the sludge cake.

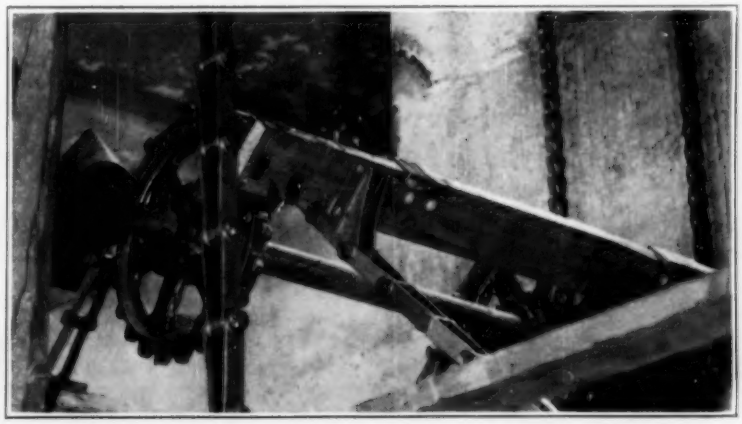
The incineration of grit with screenings at Milwaukee in a multi-zone rabble furnace has been described by Lewers.[8]

References

1 John W. Johnson, Works Supt., Buffalo Authority, Sewage Works Engrg., August, 1949, p. 386.
2 American Well Works, Bulletin No. 249.
3 Grit Chamber Velocities Controlled by Parshall Flume by Stanley T. Barker, WW&S, April, 1939.
4 Nelson M. Fuller, "Pneumatic Grit Washer" N.Y., WW&S, Oct. 1942, p. 449.
5 W. A. Kivell and N. B. Lund, WW&S, April, 1940.
6 R. D. Nichols and S. L. Tolman, Municipal Sanitation, Dec. 1938.
7 Nye Grant, Associate Member Paul A. Uhlmann and Associates, Columbus, Ohio. Eng. News-Rec. July 1949, p. 56.
8 George R. Lewers, WW&S, June, 1939.

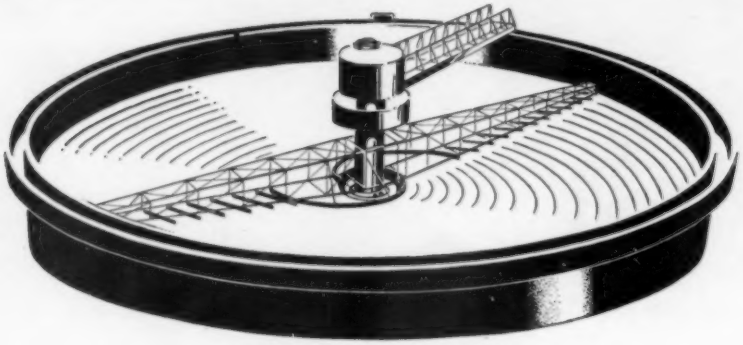


Columbus, Ohio—Jeffrey Hunting Tooth Type Sprocket



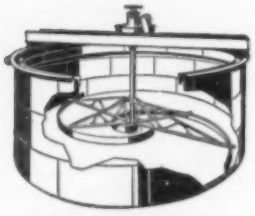
Columbus, Ohio—Flight equipment with full depth attachments. Note insert type wearing shoes

HARDINGE SANITATION EQUIPMENT



• CIRCULAR CLARIFIERS

Hardinge Circular Clarifiers are available in sizes up to 200' diameter, either center-column or beam supported for steel, concrete, wood or tile tanks. Sludge scrapers remove settled solids rapidly through central underflow discharge. Bulletin 35-D-15.

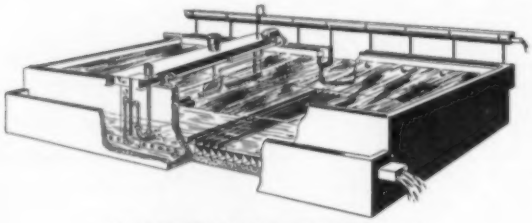


• THICKENERS

For removal of fine suspended solids from supply water, waste water and sewage. "Auto-Raise" mechanism prevents scraper breakage. Bulletin AH-442-15.

• RECTANGULAR CLARIFIERS

Especially suited for limited spaces or where sludge delivery is desired at one end of the tank. A traveling scraper and skimmer carriage removes settled solids from the tank bottom and scum from the top. Bulletin 35-D-15.



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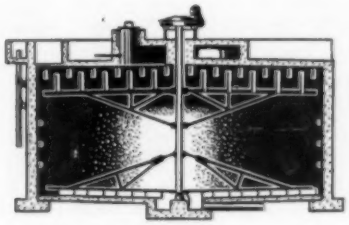

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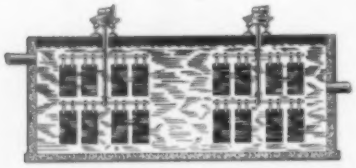

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Municipal Sewage Lagoons

by DONALD E. FRENCH

Partner, Beard & French, Associated Engineers, Kahoka, Mo.

IN the spring of 1954 the author's firm was employed by the City of Perry, Missouri, a municipality of 840 people, to make a preliminary design and cost estimate for a complete sewer system and sewage treatment facilities.

Several types of small treatment plants were considered before the initial cost estimate finally was prepared on the basis of a Spiragestor followed by a trickling filter. A conservative estimate of cost for the plant was approximately $25,000, but it was evident that it would be beyond the city's ability to finance a plant of this type in addition to a complete sewer system.

Reasons For Survey

Thus, when lagoons were investigated seriously it was as a last resort. Some of the citizens of Perry had previously mentioned the possibility of a lagoon, and the consultants had heard indirectly of lagoons in other states. At this point, however, the attitude was one of skepticism.

The initial phases of the investigation of the subject offered little reassurance. It was found that when lagoons were mentioned in sanitary engineering texts, only two or three paragraphs of very general information were given.

With few exceptions, a search of magazines and other technical publications also proved negative. The authors of the few magazine articles found had in some cases drawn conflicting conclusions. Even terminology was not uniform. For example, in North Dakota, the state which has lead in developing lagoons in the Midwest, they were called lagoons, whereas in Texas, which also has used lagoons for many years, they were called oxidation ponds. Some states even make a definite distinction between lagoons and oxidation ponds. The situation was, to say the least, somewhat confusing.

At this point people who had been observing operating lagoons were contacted. To determine the status of lagoons in the Midwest, letters were written to the Departments of Health in 19 states. The few published articles on the subject also were reviewed.

An interesting picture began to emerge. Some of the magazine articles by people who, like ourselves, had no experience with lagoons were very critical of them and advanced various theories as to why they wouldn't work. However, those who reported on actual results were unanimous in their endorsement of lagoon-type treatment. In fact, many were openly enthusiastic.

Correlation of all the information made it evident that lagoons were a proven method of sewage treatment. While not a cure-all they promise, where applicable, to provide high quality treatment at substantial savings in construction and operating costs.

The purpose of this paper, then, is to summarize the information gathered from the various sources mentioned and to give a general consensus of present thinking on the subject of municipal sewage lagoons as the author understands it. There are many closely related topics, such as production of algae for food and the use of lagoons for treatment of trade wastes, which are interesting and worthwhile. For the sake of brevity, however, this paper is limited to the subject of municipal sewage lagoons.

Since the information is from so many sources, it is not feasible to make individual acknowledgments. Possible exceptions to this are the papers received from W. Van Heuvelen, of the North Dakota Department of Health, and conversations with Jack Smith, of the Missouri Division of Health, and Glen J. Hopkins, officer-in-charge of the USPHS office in Kansas City, Mo. These sources of information have been particularly valuable. They should not, however, be held responsible for any conclusions drawn herein.

Theory Of Lagoon Action

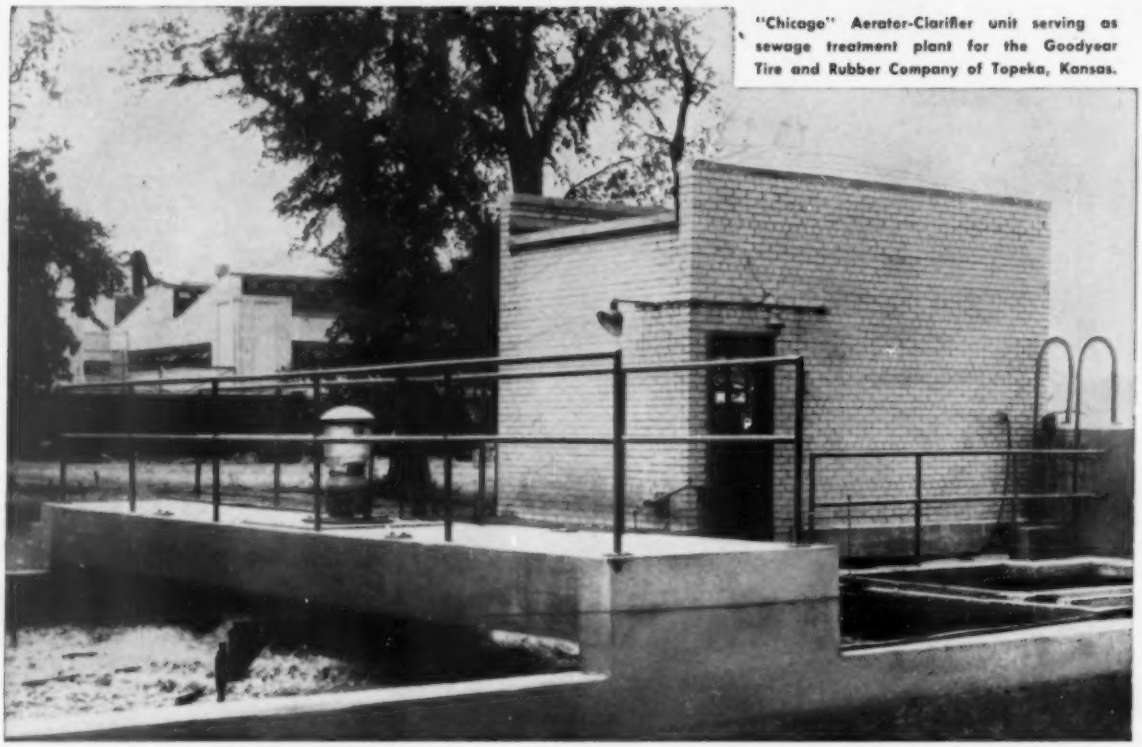
Before becoming too deeply involved in the subject let us briefly review the theory of the action occurring in lagoons.

The purpose of any sewage treatment is to alter the character of sewage so that it may be disposed of without causing a menace to health or a nuisance. Practically all modern methods of treatment—including lagoons—accomplish this by bacterial action. Since bacterial action without oxygen results in the release of hydrogen sulfide, mecaptans, and other foul smelling gases, it is necessary to provide oxygen if a nuisance is to be prevented.

Most methods of treatment accomplish this by bringing large quantities of air into contact with the sewage. This involves the use of tanks, pumps, filters, and other comparatively expensive equipment.

The sewage treating lagoon, however, obtains its oxygen through an entirely different principle. Algae, a low form of plant life containing chlorophyll, have the characteristic of releasing oxygen when they digest their food. For food they require, among other things, carbon dioxide and nitrates.

When the aerobic bacteria in raw sewage have oxygen they produce carbon dioxide and nitrates. Thus, the bacteria convert the sewage into products which the algae can use for food,



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while the algae produce the oxygen which the bacteria need.

The only equipment required is a pond of suitable area and depth with properly designed inlets and overflows. The area provided for complete treatment by present design criteria is usually one acre for each 100 persons served. This is an empirical value arrived at in the Dakotas where land is usually flat and relatively inexpensive.

Survey Results

Lagoons have been used for many years in the Southwest and elsewhere for secondary treatment. In addition, a few total treatment lagoons have been in operation for some time in North Dakota. It is only recently, however, that widespread interest has been shown in the possibilities of using lagoons for total treatment. The present status of treatment by lagoons in the states contacted is shown in Table 1.

In Table 1 it should be noted that some of the states which have approved lagoons, but as yet have none in operation, indicate that their approval is on a conditional demonstration basis. It also should be noted that practically all the states with lagoons in operation report good results.

The lagoons operating in North Dakota, South Dakota, Montana and Wyoming in most cases have been handling raw sewage. Laboratory tests by the Departments of Health of these states and by the Public Health Service indicate that B.O.D. reductions of more than 90 percent, a high degree of oxygen supersaturation, and a complete absence of odor or other nuisances is the rule rather than the exception. Most of these authorities indicated that they considered the lagoon treatment at least equal to treatment in conventional secondary plants.

Kearney Lagoon

The lagoon at Kearney, Nebraska, is especially interesting. It is operating at a much heavier continuous load than any other lagoon and is one of the few raw sewage lagoons in operation in the general latitude of Southern Iowa.

The Kearney lagoon is approximately 10 acres in area, with the bottom and sides being almost pure sand. It was put into operation in the early spring of 1954 serving approximately 12,000 people. The influent was approximately 1.4 mgd with an average B.O.D. of approximately 160 ppm. This would give a B.O.D. loading of more than 180 pounds per acre per day.

TABLE 1

Status of Sewage Treatment by Lagoons in Midwestern States

State	Sewage Lagoons		
	No. in Operation	No. Approved	Results
Arkansas	0	0	.....
Colorado	6	7	Mostly good
Illinois[a]	3	4	Good
Indiana	0	0	.....
Iowa	0	0	.....
Kansas	16	.....	Good
Kentucky	0	0	.....
Michigan	0	0	.....
Minnesota[a]	0	2	.....
Missouri[a]	0	5	.....
Montana[a]	12	2	Excellent
Nebraska[a]	6	.....	Good
No. Dakota[a]	31	36	Excellent
Ohio	0	0	.....
Oklahoma	19	.....	Good
S. Dakota[a]	11	Several	Good
Texas	100+	100+	Good
Wisconsin	0	2	.....
Wyoming[a]	3	2	Good

[a] States in which construction of raw sewage lagoons has been approved.

During the initial operation there was an appreciable loss of liquid into the underlying sand strata and for several months the lagoon operated at a depth of less than 18 inches. No nuisance developed, however, and the sand seemed to gradually seal off. The lagoon began to produce an effluent at the outlet in September 1954.

It continued to function well until several days of cloudy weather occurred in October 1954. At this time some odor developed and the load was cut to about 60 pounds of B.O.D. per acre per day. It straightened out shortly and is currently still performing satisfactorily. During the summer months B.O.D. reduction was in excess of 95 percent. Under cold weather conditions of early January a B.O.D. reduction of more than 85 percent was observed.

Coliforms Reduced

A point of special interest reported by several authorities is the fact that the concentrations of coliform bacteria in the effluent from lagoons is considerably less than that in the effluent of other types of plants.

Several theories have been advanced to account for this. One interesting theory is that the algal-bacterial symbiosis produces an enzyme or other substance which is toxic to the coliform bacteria. At any rate it is gratifying to know that in this important sanitary respect lagoons are superior to conventional plants.

Problems Seem Few

The only difficulty reported on properly designed lagoons was a few days of odor at the time the ice goes off in the spring. Reports of this condition were not widespread and extreme overload appeared to be a contributing factor in the few severe cases reported. Under the worst circumstances these odors are similar to those produced by a poorly operated or "upset" conventional plant. In practically all instances these conditions were of only a few days duration.

In all localities the lagoons have shown the ability to handle temporary overloads of several hundred percent. In the rare cases where extreme prolonged overload upset them they have recovered quickly when the overload was removed.

Interest Rising

Several of the states which reported that no lagoons have been built to date indicated that interest has been shown and that this form of treatment may be considered by them in the future. When the results being obtained and the widespread interest that is being shown are considered, it seems a safe prediction that within a comparatively short time sewage treating lagoons will be commonplace throughout the Midwest.

This widespread interest tends to put the design engineer on the spot. Although lagoons have operated quite

UPTURNED inlet pipe which discharges at center of Perry, Mo. sewage lagoon
Pointed out by Russell Itschner, Supt. of Public Works

successfully in Texas, the Dakotas, and other states, no comprehensive experiments have been undertaken to determine the best methods of operation and exact design criteria. Almost all available information is from observations of admittedly over-designed lagoons. A notable exception is the Kearney, Nebraska, lagoon previously mentioned. There are no long-range operating data for the intermediate latitudes.

The apparent conflicts of conclusions reached by some of the authorities on lagoon treatment tend to cause confusion. For example, Texas recommends that lagoons be used only for secondary treatment, whereas the Dakotas are strongly in favor of their use for total treatment. Some authorities have advocated locating the lagoon in tight soil, and even recommend bituminous or other treatment if a permeable soil is encountered. Others report very successful operation in relatively porous soil. In fact, one successful lagoon was built in almost pure sand.

More Research Needed

As previously noted, these factors tend to make the engineer's job more difficult. There is a great need for a research installation in which loadings and other factors can be varied and comprehensive studies conducted in order to determine design and operating criteria. The U. S. Public Health Service is extremely interested in adequate lagoon research, particularly for our area of intermediate latitude.

The author's organization is at present cooperating with the Missouri Division of Health and the USPHS in the design of such an installation, which it is hoped will be built in connection with a proposed municipal lagoon which will serve a Missouri city of 3,000 population. If plans go according to schedule it will be put into operation in the fall of 1955. It would seem likely that by the fall of 1956 a considerable amount of design data should be available.

It is doubtful, however, if it will be possible to postpone all action on lagoons for a year in order to obtain more precise design data. Actually, despite the lack of exact data and the conflict of opinion we are in a more favorable position than it might seem.

One striking fact is that practically all the lagoons built to date have functioned very well. Some have been built with paved bottoms; some have been built in untreated sand. Some have handled raw sewage; others have handled secondary only. Some have been loaded with 17 pounds of B.O.D. per acre per day; others were loaded with 60 pounds. Some have been so constructed that all sewage was disposed of through seepage and evaporation, whereas others produce an effluent. Some are round in shape, some square, some rectangular, and some irregular. Yet practically all are successful.

Some General Factors

Although no comprehensive experimental installations have been built, much has been learned through experimentation with some of the variables on existing lagoons. For example, it has been demonstrated that it is best to have the inlet submerged and some distance from the bank. It has also been determined that optimum depth is from 3 to 5 feet. If the depth is much less than 3 feet, cattails and other weeds become a nuisance. If deeper than 5 feet, the sunlight doesn't reach the bottom, there are no algae, and septic action occurs. To maintain a uniform depth it is, of course, necessary that the bottom be level.

In general, the dikes should resemble the bank of any well-built reservoir of similar size. The same attention should be given to the location of a lagoon as is given to the placing of a conventional plant. As previously noted, the shape of the lagoon and the texture of the soil do not seem to affect the operation of the lagoon seriously as long as a minimum operating level of at least 3 feet is maintained.

The most important point about which there is a dearth of information is the proper area. In most places where lagoons have been used extensively, land values are relatively low. In many cases the topography has been such that grading costs are also low. Under these conditions and in the absence of exact design criteria it has been good engineering practice to design on the safe side. In Iowa and Missouri, however, land values are higher, and in some cases topography makes construction rather expensive. It thus becomes very important to hold the lagoons to the smallest area that will provide satisfactory treatment.

The present generally accepted design area for treatment of raw sewage is one acre for each 100 persons served. There are several indications, however, that this is excessive. If average domestic sewage were being treated, the B.O.D. loading would be approximately 17 pounds per acre per day. Illinois allows 30 pounds per acre per day on secondary lagoons, and Texas allows 50 pounds per acre per day. The Kearney, Nebraska, lagoon for the most part is operating quite satisfactorily at a loading of 60 pounds of B.O.D. per acre per day.

Thus, all the available data seem to indicate that heavier loadings can be used. Although there are not enough data to determine exactly what the loading should be, it seems probable that we may be able to use one acre for at least 200 persons instead of the present factor of one acre per 100 persons. If more efficient meth-

ods of operation are developed we may be able to do even better. It is the problem of the design engineer to take advantage of the fact that higher loading will probably be satisfactory and yet to make sure that the city will not end up with an underdesigned lagoon.

The Missouri Division of Health has followed a policy which seems to be very sound. The preliminary design is required to be based on one acre per 100 people and enough land must be acquired and financing arranged for a lagoon of this size. However, construction of a somewhat smaller lagoon is allowed, with the provision that if health hazard or nuisance develops the full-size lagoon must be built. This policy enables the city to save money if the smaller lagoon proves satisfactory. The city is also in a position to enlarge the lagoon economically if that becomes necessary.

Summary

To summarize, properly designed lagoons are a proven means of economically and effectively treating raw sewage from small communities. While there is yet much to learn, the indications are that lagoons are gaining in acceptance and that when more exact design and operating data are available they will be even more attractive as a means of municipal sewage treatment.

Where applicable, lagoons in many cases will save municipalities considerable on construction costs. For example, the Perry, Missouri, lagoon mentioned earlier was built instead of a conventional plant. The estimated cost of the conventional plant was $25,000. The total construction cost of the lagoon, including force main, will be under $8,000. Without this savings the city would have been unable to undertake its sewerage and sewage treatment program, which included sewering the entire town as well as building the lagoon.

The lagoon also has an advantage in the matter of operation. Very few small towns adequately maintain and operate a conventional plant after it is built. Nevertheless, the success of these plants is very largely dependent upon good operation. When adequate operation and maintenance are provided the city is faced with a substantial annual cost. The lagoon, however, requires practically no operation or maintenance except caring for the dike, which should be mowed several times a year and frequently inspected for bank rat damage.

All these factors tend to make the lagoon method of sewage treatment very attractive to the small municipalities. Lagoons should not be regarded as a cure-all, however. In some instances there are factors which tend to counterbalance the advantages. The land area requirement is very large in comparison with conventional plants. Also, since the depth of the lagoon must be uniform, a considerable amount of grading may be required if the topography is unfavorable. A lagoon should not be located near public or private water supplies drawing from aquifers near the surface. If there is no suitable land near town, piping and pumping costs may become critical factors.

The economics of each case must be determined by balancing the costs of land, extra piping and pumping, grading, fencing, and other work and materials required for a lagoon against the cost of concrete, steel, buildings, piping, and equipment required for other types of plants. As noted previously, the lagoon will usually have some advantage in the matter of operation and maintenance costs.

In conclusion, it should be reemphasized that the lagoon should not be regarded as a cure-all. Each case must be given careful consideration before the type of treatment is chosen. It has been adequately demonstrated, however, that lagoons, where applicable, will provide satisfactory treatment at substantial savings in both construction and operating costs.

It is probable that there are many small towns throughout the Midwest which through the use of lagoon treatment will be able to have sewage systems which they otherwise could not afford. Viewed in this light, lagoons must certainly be considered a valuable addition to the tools of the sanitary engineer.

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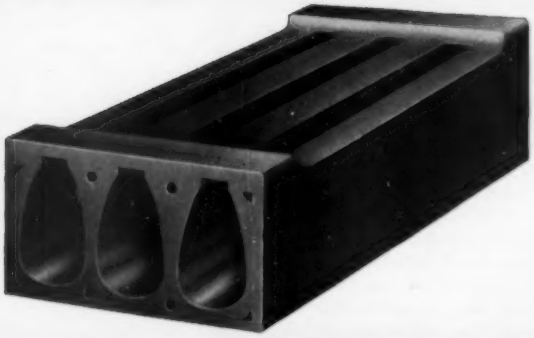

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Studies of experimental units operated in series and in parallel

By H. HEUKELEKIAN, C. B. McMENAMIN, and M. C. RAND

Messrs. Heukelekian and Rand are respectively Res. Engr. and Research Assoc., N. J. Agr. Expt. Sta., Rutgers Univ. Mr. McMenamin is Supt., Middlesex Borough Sewage Tr. Plant, Bound Brook, N. J.

THERE are a great number of high-rate trickling filters in existence in this country, and considerable information is available on the operating results, loadings, and efficiencies of such filters. A number of the installations employ double filtration. In some, the primary filter is of the high-rate type, followed by a low-rate filter. In others, both units may be of the high-rate type. Some of the installations practice recirculation; others do not. However, despite the number and variety of high-rate filters upon which data are available, there are few direct comparisons of single-stage filtration with double-stage filtration on the basis of efficiencies at different loadings.

It has been established that two-stage high-rate filters give effluents which compare favorably with standard-rate filters and even with activated sludge. Also, that they are distinctly superior to single-stage high-rate filters. The question raised in this paper, however, does not concern itself with these comparisons, but with the problem of the efficiency of a cubic yard of filter stone in single *vs.* double filtration. The question that is specifically raised is, if two filters are available which can be operated either as single-stage units in parallel or double-stage units in series, which type of treatment would give the highest efficiency with the same sewage and loadings; or, if a new plant were to be built, can the over-all size of the filters be reduced by designing a double filtration type rather than a single filtration and still obtain the desired quality of effluent. It is the purpose of this paper, therefore, to present a comparison of the results obtained in series and parallel operation of a pair of experimental high-rate filters.

The experimental units were set up at the Middlesex Borough sewage treatment plant. The plant is equipped for treatment by sedimentation and chlorination of sewage, augmented during the summer months by chemical coagulation. The dry-weather flow at the plant is 600,000 g.p.d., derived mainly from domestic sources except for 60,000 g.p.d. of waste discharged from a candied fruit manufacturing plant. The waste is high in sugars, B.O.D., and dissolved solids. The discharge of this waste into the municipal sewer increases the B.O.D. of the mixture considerably, making it difficult to obtain a desirable quality of effluent with the primary treatment facilities available, even after chemical coagulation. To meet this situation, secondary treatment of the combined domestic and industrial waste is one of the alternatives. Accordingly, the experimental filters were operated at this plant for two purposes: (1) to obtain the fundamental information mentioned above, and (2) to meet a local situation.

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Experimental Apparatus

Figure 1 is a diagram of the experimental equipment, which consists essentially of two trickling filters 15 ft. in diameter and 5 ft. deep, each followed by an upward-flow sedimentation tank. The two units may be operated either in series or in parallel.

Settled sewage from the effluent channel of the primary clarifier of the plant proper is pumped to a constant-head tank, from which the overflow is returned to the primary clarifier. The flow from the constant-head tank to the trickling filters is controlled by valves and orifice discs inserted in the lines to the mixing tanks.

Recirculation is likewise controlled by orifice discs, which regulate the flow from the clarifiers to the mixing tanks.

Sludge from the settling tanks is returned to the primary clarifier of the plant proper.

When the two filters are operated in parallel, settled sewage from the constant-head tank is allowed to flow into both the mixing tanks. The effluent from the filters is lifted to the sedimentation tanks. From each sedimentation tank a portion of the settled effluent, controlled by an orifice disc, is returned to the corresponding mixing tank for recirculation. The overflow from both settling tanks passes to the effluent channel.

For series operation, settled sewage from the constant-head tank is admitted to only one of the mixing tanks. Recirculation is accomplished the same as in parallel operation. However, the overflow from the settling tank following the primary filter is diverted to the mixing tank of the secondary filter. The effluent from the secondary filter passes to the corresponding settling tank, a portion is recirculated to the mixing tank, and the overflow from the settling tank goes to the effluent channel.

Procedure

The filters were operated from May to November during 1947, 1948, 1949, and 1950. The filters were operated in parallel during the first two years, and in series during the last two years. More data were obtained during parallel operation, as each filter during the period was dosed at a different volumetric rate and a different B.O.D. loading. The dosage rates were changed from time to time during both single and double-stage operation periods. Loadings also varied because of fluctuations in the B.O.D. of the applied sewage. Recirculation ratios were also varied from time to time during the entire period of operation.

Once or twice a week samples of the settled sewage and of the influent and effluent of each filter were taken and the 5-day 20° C. B.O.D.'s determined. Each sample so tested was a composite of samples taken hourly from 11 A.M. to 3 P.M., during which time the strength of the sewage applied to the filters was slightly above the daily average, although peak strength did not always occur during those hours. Candied fruit waste was always present in the sewage during the sampling period, which, therefore, represents the most difficult conditions for treatment.

Strength of Sewage Applied

The strength of the sewage applied to the filters was high because of the presence of candied fruit wastes. During the single-stage operation period, the average B.O.D. of 81 samples of applied sewage was 540 p.p.m., with a minimum of 135 p.p.m., and a maximum of 830 p.p.m. During the double-stage operation period, the average B.O.D. of 55 samples of sewage applied was 628 p.p.m., with a minimum of 315 p.p.m. and a maximum of 1,200 p.p.m. The strength of the applied sewage was about 3 to 4 times higher than that of normal domestic

sewage, and the strength was somewhat less during the period of single-stage operation than during double-stage filtration.

Although the candied fruit waste is deficient in nitrogen, no artificial supplementation was practiced. Since no deficiency was encountered, presumably the mixture of the waste with domestic sewage contained sufficient nitrogen for optimum biological treatment.

Results

The average results of parallel and series operation for the entire period are given in Table I. The volume of applied sewage was 3.8 m.g.a.d. during parallel operation and 3.1 m.g.a.d. during series operation. The recirculation ratio was 3.6 during parallel operation and 6.0 during series operation, including the recirculation in both primary and secondary filters. The total hydraulic load on the filter during parallel operation was 17.5 m.g.a.d., and 21.7 m.g.a.d. during series operation. The B.O.D. of the applied sewage was 540 p.p.m. and 628 p.p.m., respectively, for parallel and series operations. These high B.O.D. values of the settled applied sewage reflect the influence of the candied fruit waste discharged into the municipal sewer. The B.O.D. loads applied during the two periods were nearly alike at 2.5 lb. per cu. yd. per day. However, the effluent during single-stage operation had a B.O.D. of 110 p.p.m., and during parallel operation 39 p.p.m., giving 80 and 89 per cent B.O.D. reductions, respectively, by secondary treatment.

The results are grouped in ranges of B.O.D. loading in Table II for parallel operation, and in Table III for series operation. The recirculation ratios were high for low loadings and decreased with higher loadings. This was not intentional; it would have been more logical either to keep the recirculation ratios constant for different loadings or to increase them with higher loadings. It was, however, dictated by pump capacity, which did not permit higher rates of application of sewage with higher recirculations. It is hoped that in future experiments results will be obtained indicating the effect of different rates of recirculation at critical loadings to determine the minimum recirculation with maximum loadings without deteriorating the quality of the effluent.

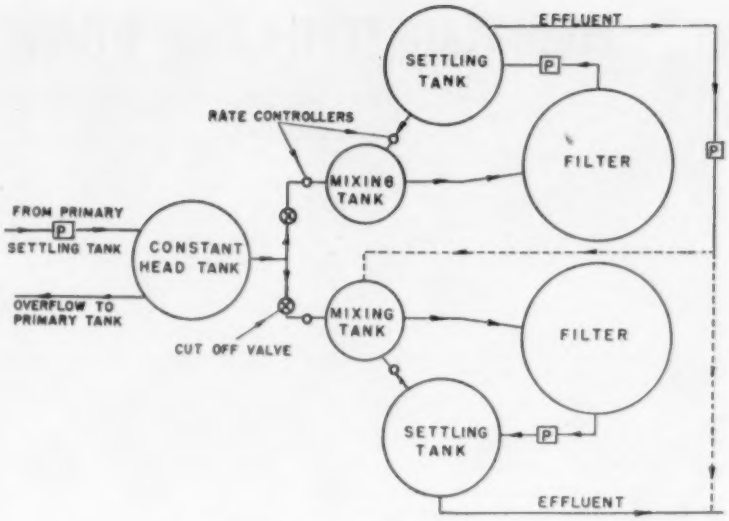

FIGURE 1.—Flow diagram of experimental high-rate trickling filter plant.

Table II

RESULTS OF PARALLEL OPERATION

Loading (lb. B.O.D.)[1]	No. of Tests	Volume Applied (m.g.a.d.)	Recirc. Ratio	B.O.D. Effl. (p.p.m.)	B.O.D. Red. (%)
1.0	5	2.6	6.1	51	79.5
1.0-1.5	16	1.8	4.8	60	88.2
1.6-2.0	14	2.8	4.5	65	87.4
2.0-2.5	15	3.2	4.4	90	83.5
2.6-3.0	6	4.4	3.6	97	82.2
3.1-3.5	6	6.3	2.3	162	68.7
3.6-4.0	6	5.5	2.2	194	66.1
4.1-4.5	4	5.3	2.2	186	69.5
4.6-5.0	5	6.4	2.2	197	66.5
5.1-6.0	4	6.4	2.0	234	65.4

[1]Pounds B.O.D. per cubic yard per day.

Table II shows that the B.O.D. of the effluent increased quite regularly with increasing loading. The rate of change of effluent B.O.D. is not quite constant, but shows a distinct break at a loading of 3.0 lb. per cubic yard per day. This break is also reflected in the percentage reduction. At loadings of 1 to 3 lb., the removal averages more than 80 per cent. However, when the loading is increased to more than 3 lb. per cubic yard, the reduction drops abruptly to a value of less than 70 per cent, and remains fairly constant in the range from 65 to 70 per cent throughout the range of loadings tested.

Table III shows the results of 2 years' series operation. The loadings are calculated on the basis of the total volume of media in both filters. In series operation, both the effluent B.O.D. and the percentage B.O.D. removal are approximately constant up to a loading of 2.5 lb. per cubic yard per day. Above that loading, the effluent B.O.D. increases, without a material decrease in the percentage reduction.

A comparison between series and parallel operation is shown graphically in Figure 2. It is clear that parallel operation give a higher B.O.D. in the effluent for any given loading. At a loading of 1 lb. per cubic yard per day the effluent from parallel operation has about twice the B.O.D. of the effluent produced by series operation. At a loading of 4 lb. the factor is about 2; but with loadings between 1 and 2.5 lb. the effluent B.O.D. in series operation is about constant, whereas in parallel operation there is a gradual increase of effluent B.O.D. with increasing applied load. At a loading of 2.5 lb. per cubic yard per day, the most efficient point for series operation, the effluent B.O.D. produced by series operation is only one-

Table III

EFFECT OF INCREASED LOADING ON THE QUALITY OF THE EFFLUENT IN SERIES OPERATION

Loading (lb. B.O.D.)[1]	No. of Tests	Volume Applied (m.g.a.d.)	Recirc. Ratio	B.O.D. Effl. (p.p.m.)	B.O.D. Red. (%)
1.0	2	1.6	10.2	21	96
1.0-1.5	9	2.4	8.3	20	96
1.5-2.0	9	2.5	8.0	19	96
2.0-2.5	8	3.0	5.84	22	96
2.5-3.0	8	3.5	4.7	43	92
3.0-3.5	9	3.7	4.4	42	93
3.5-4.5	8	4.2	5.0	75	88
4.5-5.5	2	4.0	4.0	69	93

[1]Pounds B.O.D. per cubic yard per day.

Table I

AVERAGE RESULTS OBTAINED DURING PARALLEL AND SERIES OPERATION PERIODS

Operation	No. of Tests	Volume[1] Applied (m.g.a.d.)	Recirc. Ratio	B.O.D. Applied (p.p.m.)	B.O.D. Applied (lb.)[2]	B.O.D. In Effl. (p.p.m.)	B.O.D. Red. (%)
Parallel	81	3.8	3.6	540	2.6	110	80
Series[3]	55	3.1	6.0	628	2.5	39	89

[1]Volume of untreated waste, excluding recirculation.
[2]Pounds B.O.D. per cubic yard per day.
[3]Volume of sewage and recirculated water and B.O.D. load applied are on the basis of a unit volume of stone in both primary and secondary filters.

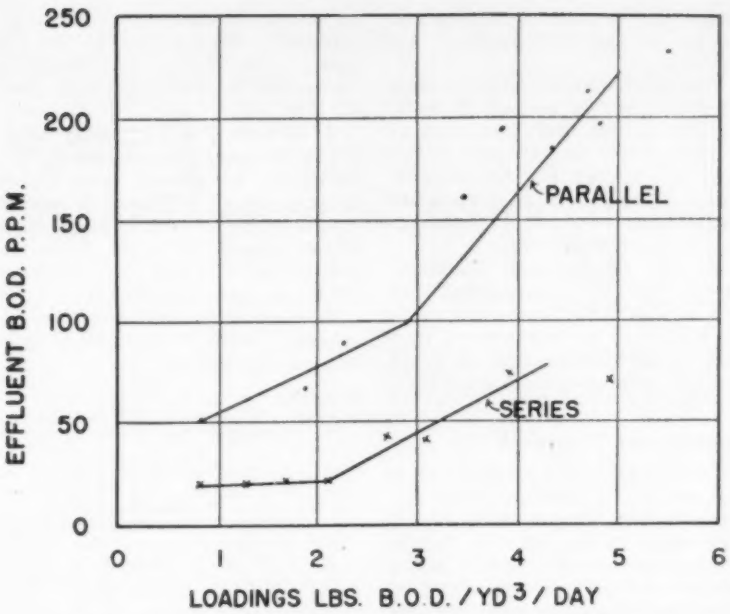

FIGURE 2—Comparison of the effect of loading on the B.O.D. of effluent in series and parallel operations.

third that produced by operating the filters in parallel. Thus, at any loading between 1 and 4 lb. of B.O.D. per cubic yard per day, the effluent B.O.D. from parallel operation averaged 2 to 3 times as high as that produced by series operation.

It follows, from what has been said, that a given effluent standard permits higher loadings in series operation than in parallel operation. For example, an effluent standard of 100 p.p.m. B.O.D. could be met by operating the filters in parallel at a loading of 2.75 lb. per cubic yard, or by operating them in series at a loading of 4.25 lb. On the other hand, an effluent of 20 p.p.m. B.O.D. could be produced by operating the filters in series at a loading of 2.5 lb., whereas no loading in the range tested was low enough to produce consistently an effluent of this quality in parallel operation.

Discussion

The results of this study show that double filtration systems can handle greater B.O.D. loadings and give lower B.O.D. values in the effluent than can be accomplished by single filtration. For instance, with a loading of 2.5 lb. of B.O.D. per cubic yard of stone, a 20-p.p.m. B.O.D. in the effluent could be obtained with double filtration, whereas with the lowest loading obtained with single filtration, 1.0 lb. per cubic yard, the B.O.D. in the effluent was 50 p.p.m. In other words, the efficiency of a cubic yard of stone is at least 2.5 times as great when used in double filtration as it is in single filtration. It should be noted that the loadings given in the double filtration are on the basis of total volume of media in both primary and secondary filters combined. The effluent quality in the loading range from 1 to 2.5 lb. per cubic yard per day is constant at 20 p.p.m. B.O.D. with double filtration. Beyond this range it gradually increases with increasing loading until at about 4.5-lb. loading it reaches 75 p.p.m. The increase in the effluent B.O.D. in the single-stage filtration starts at 1.0-lb. loading and increases gradually until at 4.5-lb. loading it reaches 200 p.p.m. To obtain a 50-p.p.m. B.O.D. in the effluent the B.O.D. loading in the single-stage filtration cannot exceed 1.0 lb. per cubic yard, whereas the same quality of effluent can be obtained with double-stage filtration at a loading rate of 3.0 lb. per cubic yard. The question may be raised as to whether the observed superiority of series operation may not be attributed to the higher over-all recirculations practiced during that period. Although the results do not warrant a positive assertion on this point, it does not seem that an increase in the average recirculation ratio from 3.6 during the parallel operation period to 6.0 during the series operation period could account for the differences obtained because the lower recirculation ratio should prove adequate and increasing the recirculation beyond this should not be of additional value. Furthermore, the total hydraulic loads were 17.5 and 21.7 m.g.a.d., respectively, during parallel and series operation—well beyond the critical flows of 7 to 12 m.g.a.d. A closer analysis reveals that the effluent B.O.D. was 51 p.p.m. during parallel operation with a loading less than 1.0 lb. B.O.D. per cubic yard per day and with a recirculation ratio of 6.1; in series operation a B.O.D. in the effluent of 22 p.p.m. was obtained with 2.0 to 2.5 lb. B.O.D. per cubic yard per day (average, 2.1) and with a recirculation ratio of 5.8. Thus, with nearly equal recirculation ratios better effluents were obtained at more than double the loadings in series operation than in parallel operation. Similar relationships were obtained from results in which nearly equal recirculation ratios are available during the periods of parallel and series operations, as follows:

Recirculation Ratio		Loading (lb. B.O.D./ cu. yd./day)		Effluent B.O.D. (p.p.m.)	
Parallel	Series	Parallel	Series	Parallel	Series
6.1	5.8	1.0	2.1	51	22
4.8	4.7	1.3	2.7	60	43
4.4	4.4	2.2	3.1	90	42

It would, however, be desirable to confirm this point in order to eliminate the possibility of superior performance of series operation arising from the higher recirculation ratios employed.

Information obtained from experiments conducted at Birmingham, England, over a number of years[4,7] with the comparison of single-stage *versus* double-stage filtration with periodic change in the order of filters in series operation, indicates that the volumetric dose on single filters could not be increased beyond 96 gal. (U.S.) per cubic yard per day without impairing the quality. Effluents with comparable quality could be obtained with double alternating filters with rates of application as high as 288 to 300 gal. (U.S.), again a ratio of efficiency 3 times as high as the single-stage filter. True, even these higher rates of volumetric applications on alternating double filtration when translated to loading rates give values of only 0.4 lb. B.O.D. per cubic yard, which is in the upper range of loading of standard filters in the United States. The effluents in the Birmingham experiments had a B.O.D. of 10 p.p.m. and nitrate-nitrogen of 20 p.p.m., as compared with the 25 p.p.m. B.O.D. obtained in the experiments reported herein with double filtration at a loading value of 2.5 lb. per cubic yard. It is also true that these results in England were accomplished with periodic alternation in the order of filters, otherwise the filters would clog and deteriorate, whereas at no period of the current study, either with single-

stage or double-stage operation, was there any indication of clogging. This may be ascribed to the fact that recirculation was practiced instead of alternation.

A study of two-stage fixed sequence *versus* single-stage biological filtration, both in enclosed artificially ventilated deep filters as reported by Dekema and Krige[2] from South Africa is also of interest in comparison with the results reported herein, despite the obvious differences in the design of filters in the two studies. The authors concluded that 33.8 per cent more flow could be applied and 31 per cent greater removal of B.O.D. accomplished per cubic yard of stone in two-stage filtration than in single-stage with equal purification.

Fischer and Tompson's[3] results dealing with the shallow recirculated filters at Petaluma, Calif., are, on the other hand, somewhat inconclusive in establishing the relative efficiencies of the two types of filters because on the basis of relatively few analyses, the average figures give 110 p.p.m. B.O.D. in the effluent with 5.9 lb. loading per cubic yard per day with single-stage, and 35 p.p.m. B.O.D. in the effluent with 3.1 lb. B.O.D. per cubic yard applied on the two-stage unit. The lower B.O.D. values in the two-stage systems cannot be definitely attributed to double filtration, because they were accomplished with lower loadings than in the single-stage operation.

It is similarly difficult to draw conclusions as to the relative merits of double filtration *vs.* single filtration on the basis of the results obtained at Liberty, N.Y.[1], as the filters here are operated throughout the year in series, except that in winter lower loadings are applied and recirculation is not practiced.

Walton[6] concluded that single-stage filtration gives an over-all 75 to 85 per cent B.O.D. reduction, with an average of less than 80 per cent for the plants studied. For two-stage filtration, the over-all B.O.D. reduction ranged from 85 to 95 per cent, with an average of 90 per cent.

Moore, Smith, and Ruchhoft[5] showed that with nearly equal loadings (2.4 lb. B.O.D. per cubic yard) the B.O.D. in the final effluent from single-stage operation was 31 p.p.m. and that from double-stage operation was 24 p.p.m.

Summary and Conclusions

Two experimental filters 15 ft. in diameter and 5 feet deep were operated for two seasons from May to November on the basis of parallel operation and for two additional seasons on the basis of series operation. Recirculation was practiced. The loadings were varied by (a) changing the flows periodically and (b) fluctuations of B.O.D. in the applied sewage. The sewage contained candied fruit waste containing sugar and high soluble B.O.D. The average B.O.D. of the applied sewage was 540 p.p.m. during single-stage operation and 628 p.p.m. during double filtration. The results based on the B.O.D. of the effluents warrant the following conclusions:

1. The efficiency of the double filtration system was 2.5 to 3 times as high as that of single filtration.

2. A loading of 1 lb. of B.O.D. per cu. yd. per day gave an effluent with a B.O.D. of 50 p.p.m. in single-stage filtration, whereas with double-stage filtration a 20-p.p.m. B.O.D. was obtained in the effluent with a loading as high as 2.5 lb. B.O.D. per cubic yard per day.

3. Between 1 to 2.5 loading range, double filtration gave constant B.O.D. values in the effluent, with higher loads resulting in a gradual increase in B.O.D. of the effluent. In single-stage filtration the B.O.D. in the effluent began to increase with loadings above 1.0 lb. per cubic yard per day.

4. Ponding troubles were not encountered with either system of operation at any loading.

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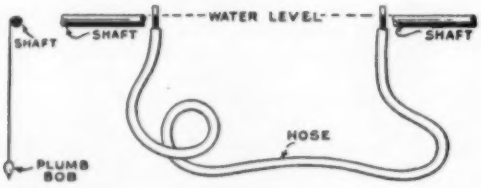
How to Level and Align Shafts by Simple Method



The accompanying sketch shows how to do it. Slip gauge glasses into each end of an ordinary rubber hose and fill with enough water so that the level will show in each glass, as indicated.

When filling the hose with water, care must be exercised to be certain that all air is gotten out of the hose. Hold it in a U-position when filling. Do not attempt to fill it by immersing the hose in a tub of water. Also, one end of the hose must not be warmer than the other end. If the water in one end is warmer it will occupy greater volume and the level will not be true. In other words, get rid of all of the air and use water of the same temperature throughout.

The sketch also shows one of the simplest methods by which shafting can be aligned. Suspend several plumb bobs from the shaft as shown, all from the same side of the shaft. It is then possible to glance along from one end to the other and one can see whether or not the cords supporting the plumb bob are in perfect alignment. If they are not in alignment, the shafting is not straight and should be rectified. A cord stretched lengthwise near the vertical cords enables one to measure the exact amount of misalignment and assist in making the shaft straight.

Design of Activated Sludge Plants

A rational approach to the subject

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ALTHOUGH additions to knowledge of the activated sludge process appear in the technical press almost monthly, there has been little, if any, advancement in design criteria during the past thirty years. A national survey[1] of State Health Department requirements made in 1948 showed that only nine states had any specific requirements concerning activated sludge plant design. For diffused air plants, those states specified an aeration period of 4 to 8 hours and an air supply of 0.5 to 2.0 cubic feet per gallon of sewage. Aeration periods were based on sewage flow plus return sludge, which was usually specified to be 25 percent of the sewage flow.

The designs of the earlier activated sludge plants were based largely on the results of protracted and exhaustive pilot plant operations. Unfortunately, the designers of many of the more recent plants have had little or no experience in the actual operation of the process. The fact that many such plants have proved highly successful is due more to the ingenuity of the operators and the helpfulness of design criteria privately developed by equipment manufacturers, than to the skill of the designer or the adequacy of State Health Department regulations.

The newer "Ten State Standards for Sewage Works"[2] consider the B.O.D., as well as the volume of the sewage or waste to be treated, and so are superior to the earlier criteria. However, neither they, nor any of the design standards developed by equipment manufacturers, make any mention of the amount of activated sludge to be carried.

Because activated sludge is essential to the process, and because the amount of sludge carried has a marked influence on the functioning of the process, it would appear essential for the designer to select the optimum, or maximum, sludge load and then design the plant to carry that load. The failure to properly evaluate this important factor may well explain the prevalence of sludge bulking and the frequently repeated statement that "the process requires expert operating attention and is easily upset by industrial wastes."

Sludge reæration is another phase of design which is totally ignored by practically all design criteria. Many of the early plants included sludge reæration, but most of those constructed during the 1930's omitted such provisions. Nevertheless, Hatfield at Decatur and Kraus at Peoria[5] have been making old plants operate at far above their original design loads for decades by sacrificing mixed liquor æration in order to gain the separate sludge reæration not provided in the original designs. Since World War II sludge reæration, in various forms, has gained in popularity. Certainly any modern design criteria should evaluate sludge reæration as well as total sludge load.

This paper presents an approach to the design of an activated sludge plant which is believed to be more rational than that afforded by any presently accepted criteria. Although the suggested procedures are applicable to sewage or wastes of unusual strengths, they are not intended to be a substitute for actual pilot plant investigations wherever such investigations are feasible. Like most other design criteria, they must be tempered with the judgement of one familiar with the design, construction and operation of the process. No criteria can be set up that will insure the sucecss of an inexperienced designer.

This paper is not based on any original laboratory or plant-scale experiment. Instead, it is based entirely on a re-evaluation of the published work and findings of others. The author gratefully acknowledges the value of the original investigations.

Optimum Quantity of Sludge

When an adequate quantity of well-activated sludge is mixed with sewage or waste, the waste is clarified; that is, most of its pollutants and many bacteria and protozoa are adsorbed by the sludge. In the presence of an adequate supply of oxygen, some biological forms die off or remain dormant while others multiply rapidly. By their growth these organisms convert pollutants to carbon dioxide, sulfates, nitrates and the living protoplasm of their bodies. During the progress of this biological oxidation, enzymes may be secreted which hasten and improve clarification.

Both oxidation and clarification take place most rapidly when activated sludge and sewage are first brought together, providing there is sufficient oxygen available. Clarification or adsorption will be substantially complete in 20 to 40 minutes, but several days may be required for complete oxidation.

A balance must be maintained between the two. If oxidation lags behind adsorption, the settleability of the sludge deteriorates and "bulking" is encountered, although clarification may still be excellent. If oxidation lags still farther behind, the sludge will lose much of its clarifying power, although its settleability may improve and become even better than that of fully activated sludge. Such a sludge can still produce considerable purification, even though it cannot yield the clear, sparkling effluent typical of the conventional activated sludge process.

TABLE 1

Conventional Activated Sludge
(No Separate Sludge Reaeration)

Plant		Period	Sewage to Aerators			Mixed Liquor	
No.	Location		Flow, mgd	Susp. Sol., ppm	5-Day B.O.D., ppm	Susp. Sol., ppm	Sludge Age*, days
1	Ann Arbor, Mich.	1944-46	5.0	128	182	1844	4.2
2	Ann Arbor, Mich.	1947	6.7	107	169	1850	3.87
3	Baltimore, Md.	1945	10.64	92	217	937	4.74
4	Chicago S.W.	1946	288.0	.....	129	1930	.....
5	Chicago S.W.	1951-52	794.0	105	97	2330	4.2
6	Chicago N.S.	1946	197.5	.....	97	2400	.....
7	Chicago N.S.	1946-50	213.0	88	77	2000	5.7
8	Chicago Calumet	1946	71.8	.....	94	2190	.....
9	Chicago Calumet	1946-50	77.0	105	87	2230	5.4
10	Cleveland East	1940-45	86.9	146	91.5	2180	4.89
11	Ft. Wayne, Ind.	1941-45	14.92	151	161	2420	6.77
12	Gary, Ind.	1941-45	19.0	101	77	1325	3.25
13	Hagerstown, Md.	1943-46	3.87	286	254	1808	2.37
14	Hammond, Ind.	1942-46	20.2	152	135	2196	5.90
15	Indianapolis, Ind.	1942	17.83	215	182	2400	4.87
16	Indianapolis, Ind.	1943	7.98	224	181	2600	6.47
17	Indianapolis, Ind.	1944	11.34	234	193	2800	8.15
18	Jackson, Mich.	1942-46	8.04	144	118	2801	5.41
19	Madison, Wis.	1947	7.60	.....	157	1094	.....
20	Marion, Ind.	1942-45	3.92	117	134	2625	5.30
21	Marshalltown, Iowa	1943-46	3.35	130	177	2500	7.45
22	Milwaukee West	1945	65.4	315	332	3000	4.20
23	Milwaukee East	1945	56.0	315	332	3000	3.46
24	Omaha, Neb.	1946	2.54	149	128	1720	5.84
25	Pontiac, Mich.	1946	4.8	73	125	1200	3.94
26	Richmond, Ind.	1942-46	5.45	92	113	1680	6.20
27	Springfield, Ill.	1942	9.2	81	74	1580	5.78
28	Springfield, Ill.	1937-41	7.8	120	132	1863	4.86
29	Syracuse, N. Y.	1947	4.31	.....	236	2218	.....
30	Two Rivers, Wis.	1946	0.98	86	114	1500	9.16

* Gould sludge age (See Ref. 3)

It is these flocculated, or partially activated, sludges that are typical of most of the newer "modified æration" or "high-rate activated sludge" processes.

On the other hand, if oxidation materially exceeds adsorption much of the sludge will be destroyed by wet combustion; the remaining floc particles become very small and compact. Such a sludge does not produce a sparkling clear effluent, although nitrification may be high. Apparently some of the sludge is broken up into "pin point floc." These particles do not settle in final clarifiers, even though the main body of the sludge has a low Mohlman index. A nitrifying sludge does not bulk. However, liberation of gaseous nitrogen may cause chunks of sludge to rise to the surface of final tanks.[7]

There is a close relationship between the oxidation-adsorption balance and the amount of sludge carried in an æration tank. The less the amount of sludge carried in proportion to the daily pollutional load, the higher will be the adsorption of pollutants per unit weight of sludge. Either more time for oxidation, or a higher rate of oxidation, must be maintained if bulking is to be avoided in the conventional process. Although bulking would not occur in the modified æration processes, a further drop in clarification and degree of treatment would result.

The operator can measure the quantity of sludge in his æration tank by simply determining the mixed liquor solids concentration. However, this is true only because the volume of his tank is fixed.

The designer, on the other hand, has an infinite choice of æration tank volumes. Therefore, he must consider that volume as well as the concentration of solids if he is to have a true measure of sludge quantity.

The "Gould sludge age"[3, 8, 9] is the ratio of total weight of suspended solids in the mixed liquor to the weight of suspended sewage solids introduced into the ærators daily. It should be noted that this definition assumes that there are no significant accumulations of sludge in the final settlers. Edwards[8] and Gould[3, 9] state that for the conventional process a sludge age of at least 3 days is necessary and 4 days is desirable; for the high-rate process the age should range from 0.4 days in cold weather to 0.2 days in hot. Between the conventional and modified processes there is an intermediate zone (that is, sludge age 0.5 to 3.0 days) where a high Mohlman index and a poorly settling sludge is encountered.

This concept of sludge age implies that the suspended solids in the mixed liquor are simply an accumulation of suspended solids removed from the incoming sewage. Actually, the mixed liquor solids in a conventional plant are primarily zoogleal masses of bacteria, together with large numbers of protozoa and other microscopic organisms.

Although the sludge age concept has proved useful in the New York City plants, its application to plants treating wastes having a different

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TABLE 1 (Continued)

Plant No.	B.O.D Applied, lb per day: Per 100 lb Mixed Liq. Sol.	B.O.D Applied, lb per day: Per 1000 cf Aeration Tank Vol.	Air Used, cu ft: Per Gallon	Air Used, cu ft: Per lb B.O.D. Remov.	Return Sludge, percent by Vol.	Aeration Period, hr: Sewage Only	Aeration Period, hr: Mixed Liquor	Removal, Percent: Susp. Sol.	Removal, Percent: 5-Day B.O.D.	Reference
1	34.0	39.0	1.05	770	32.0	6.99	5.3	90.7	89.6	6
2	41.1	47.1	0.92	703	30.8	5.36	4.1	89.0	92.3	6
3	49.9	28.8	1.24	728	21.5	11.25	9.27	91.3	93.6	6
4	17.7	21.0	0.86	876	47.9	8.7	5.9	.....	91.5	6
5	21.8	32.0	0.68	905	38.5	4.6	3.3	86.0	92.0	13
6	14.8	22.1	0.49	645	24.0	6.56	5.3	.....	93.8	6
7	15.4	19.0	0.48	800	22.7	6.0	4.9	88.5	92.5	13
8	15.7	21.6	0.48	677	25.9	6.53	5.2	.....	90.4	6
9	15.4	19.0	0.48	740	24.4	6.1	4.9	87.0	87.5	13
10	12.5	17.4	1.06	1600	24.9	7.73	6.2	90.8	86.9	6
11	15.8	23.7	0.95	773	30.5	10.0	7.7	89.1	91.0	6
12	23.5	19.4	0.47	796	33.2	5.85	4.4	92.9	89.6	6
13	39.0	44.1	0.92	500	31.5	8.8	6.7	95.5	86.8	6
14	14.4	19.9	0.66	655	51.9	10.9	7.2	88.8	91.5	6
15	17.3	26.1	1.45	847	27.2	10.5	8.28	96.7	95.0	21
16	12.5	27.0	1.68	1060	70.0	13.45	7.9	94.2	92.2	21
17	10.1	16.5	1.52	1095	83.3	16.35	8.9	97.9	94.8	21
18	14.9	26.4	0.65	690	15.5	6.7	5.8	88.5	94.9	6
19	38.8	26.4	1.23	690	51.6	9.1	6.0	.....	77.1	6
20	21.6	35.4	0.89	886	30.8	5.7	4.34	89.8	89.7	6
21	18.3	28.6	1.45	1245	31.3	9.22	7.03	62.3	79.2	6
22	25.2	47.0	1.90	725	24.9	10.55	8.45	93.6	94.6	6
23	30.3	52.0	1.26	481	21.5	9.57	7.88	95.2	94.8	6
24	14.7	15.8	1.04	1210	60.4	12.2	7.6	79.9	80.5	6
25	43.5	32.5	0.83	886	20.8	5.75	4.77	86.3	90.0	6
26	19.8	20.6	0.39	435	28.5	8.22	6.4	82.6	94.7	6
27	15.9	15.6	0.64	1120	38.1	7.6	5.5	90.2	89.3	6
28	22.6	23.5	0.70	710	27.6	8.45	6.6	90.9	90.2	6
29	34.6	47.8	1.23	1410	26.2	7.57	6.0	.....	86.4	6
30	14.6	13.7	.....	.....	48.0	12.5	8.44	80.3	90.9	6

ratio of B.O.D. to suspended solids is questionable. Heukelekian, Orford Manganelli[10] found that the rate of activated sludge accumulation was primarily a function of the B.O.D. input to the process. This indicates that the total quantity of the sludge carried in a plant should be correlated with the daily B.O.D. load imposed on the process. Although such a parameter has not been widely used, the National Research Council[11] found a relationship to exist between the Mohlman index and the average weight of B.O.D. entering the ærators per day per pound of suspended solids in them and the final clarifiers. Okun[12], in his bio-precipitation studies, found the efficiency of B.O.D. removal to be related directly to weight of total, or volatile, solids in the unit and inversely to the organic loading.

Table 1 summarizes published operating data on numerous conventional activated sludge plants. Table 2 contains similar data for several modified plain æration plants.

Fig. 1 has been prepared from those data to show the relationship between B.O.D. loadings and removals per 100 pounds of mixed liquor suspended solids. Curve A shows the data for conventional plants; Curve B is plotted from all data.

The curves indicate that the activated sludge process alone, exclusive of primary treatment, can be expected to yield about 90 percent B.O.D. reduction as long as the daily 5-day B.O.D. load does not exceed about 50 pounds per 100 pounds of suspended solids in the æration tanks. If higher loads are applied, lower percentage reductions result. At a load of 400 pounds, the reduction is only about 54 percent.

The change in slope of the curve occurs at loadings between 50 and 100 pounds. This probably represents the middle ground between the conventional and high-rate processes where severe bulking is likely to be encountered.

Thus, as far as the conventional process is concerned, it appears that the maximum B.O.D. load should not exceed 50 pounds per day per 100 pounds of mixed liquor solids. Even at design, the average load should be somewhat less. It is suggested that moderate to large plants be designed for an average of 30 to 40 pounds. Extremely small plants that will not receive 24-hour attendance or skilled operation, might be designed for loadings of only 20 to 30 pounds of B.O.D. per 100 pounds of sludge solids, even though such a practice will increase their power requirements.

Although that portion of Curve B which applies to loadings in excess of 100 pounds of B.O.D. per 100 pounds of solids is based on relatively few rather scattered points, it may be helpful in selecting the weight of mixed liquor solids required to obtain any predetermined degree of B.O.D. reduction from modified æration processes. In making that selection, care should be taken to avoid minimum loadings of 100 pounds or less of B.O.D. per 100 pounds of solids, in

order to minimize the chance of bulking, even though the curve indicates that B.O.D. reduction would be greater at that loading than at higher loadings.

Until more is known about modified æration processes, it might be well for the designer to consider a combination of primary and conventional activated sludge treatment to yield the same over-all B.O.D. reduction as that to be expected from modified æration. By so doing, he would avoid the pitfalls inherent in designing for any new and poorly understood processes.

In any event, the previously described procedure offers a method for selecting the sludge load for which the plant is to be designed. Thus, if it is required to treat 24 mgd of settled sewage having a B.O.D. of 200 ppm by the conventional activated sludge process, the B.O.D. input to the æration tanks will be 24 x 8.34 x 200, or 40,000 pounds per day. If the B.O.D. loading is limited to 35 pounds per day per 100 pounds of sludge solids, a total of 40,000 x 100/35, or about 114,300 pounds of sludge solids are required. They might all be carried in æration tanks, or a portion of them might be carried in a separate sludge reæration tank. The volume of the tanks required would depend on the concentration of solids in them.

Without separate sludge reæration, a 5-mg æration tank with a mixed liquor solids concentration of 2,740 ppm, or a 10-mg æration tank with a solids concentration of 1,370 ppm might be used.

If a solids concentration of 4,800 ppm was carried in a 2-mg separate sludge reæration tank, then an æration tank of only 2-mg capacity with a mixed liquor solids concentration of 2,050 ppm would suffice.

In all three cases, the true sludge age would be the same. Therefore, assuming a continuous and adequate oxygen supply, the same average oxidation-adsorption balance, and hence the same sludge condition, would be maintained.

However, the combined æration and reæration tank volume per pound of B.O.D. applied would be vastly different.

In the three foregoing examples the combined æration volume per pound of applied B.O.D. would be 16.7, 33.4 and 13.4 cubic feet, respectively (Fig. 2). This illustrates the fallacy of setting up a volumetric B.O.D. loading criteria for æration tanks without giving consideration to their sludge content, as is done in the "Ten State Standards"[2] or many of the equipment manufacturers' design criteria.

Such a volumetric requirement may be likened to trickling filter design practice where B.O.D. loadings are related to volume of filter stone. It is not the stone, but the biological growth on the stone, that accomplishes the purification. However, since neither the designer nor the operator can measure the amount of such growth, we have been content with a correlation between B.O.D. load and stone volume.

Such is not the case in the activated sludge process. There the amount of growth can be readily measured and controlled. Therefore, it should be a governing factor in plant design.

Return Sludge Capacity

No doubt there are limiting maximum concentrations of solids that may be carried in either æration or sludge reæration tanks. However, it will be shown that if the rate of sludge return is adequate to prevent undue accumulations of sludge in final settlers during periods of high Mohlman index, the solids concentrations in either æration or reæration tanks will not be excessive.

An average Mohlman index of about 100 is generally considered very satisfactory at conventional activated sludge plants of the diffused air type. However, Pearse and his committee[14] show that even at plants where the average index is about 100, the daily index may range from a minimum of 30 to a maximum of 300 to 400.

The maintenance of a constant B.O.D. to solids loading would probably reduce much of that variation, but in view of the highly variable B.O.D. input to most plants, such an ideal situation is impossible of attainment. Therefore, the designer should provide for satisfactory operation at a Mohlman index considerably above

TABLE 2

Plain Aeration and High-Rate Activated Sludge

Plant		Period	Sewage to Aerators			Mixed Liquor	
No.	Location		Flow, mgd	Susp. Sol., ppm	5-Day B.O.D., ppm	Susp. Sol., ppm	Sludge Age*, days
50	Ann Arbor, Mich.	1945-46	5.3	103	171	150	0.40
51	Indianapolis, Ind.	1942	42.23	215	182	.....	0.27*
52	Indianapolis, Ind.	1943	53.36	224	181	.....	0.33*
53	Indianapolis, Ind.	1944	51.92	234	193	.....	0.31*
54	Philadelphia N.E.	Jan.-Mar. 1954	79.8	132	132	522	0.80
55	Philadelphia N.E.	Oct.-Dec. 1953	82.3	106	130	399	0.73
56	NYC Owls Head	July 1952-53	85	160	170	360	0.23
57	NYC Jamaica	1952	51	168	109	850	0.40
58	NYC Rockaway	July-Aug. 1953	18	119	105	990	0.59
59	Syracuse, N. Y.	Nov. 1944-April 1945	4.59	83	78	.....	0.34*
60	NYC Jamaica	Oct.-Dec. 1943	33.7	211	152	384	0.43
61	NYC Jamaica	Dec. 1943-Feb. 1944	29.5	283	155	626	0.31
62	NYC Jamaica	Mar.-May 1944	32.0	193	136	580	0.79
63	NYC Jamaica	June-Aug. 1944	33.0	206	111	634	0.38
64	NYC Jamaica	Aug.-Sept. 1944	37.3	202	105	365	0.20
65	Bowery Bay	1944	37.8	113	103	505	0.60

* Gould sludge age (See Ref. 3)

* Based on assumption that the average suspended solids in aerator is same as that in entering sewage.

100. It is suggested that moderate to large plants be designed for an index of 250 and small plants, where continuous skilled operation is improbable, be designed for an index of 350.

Undue retention of sludge in final settlers retards biological oxidation. In 1940, Bloodgood[15] stated:

"There is one rule that we have established for activated sludge plant operation: the return sludge concentration must never be allowed to exceed the sludge index (expressed as percent solids). This has proved an excellent guide, as following this rule does not permit the retention of sludge in settling tanks long enough to become damaged."

The sludge index expressed as percent solids is the Donaldson index, or $\frac{100}{\text{Mohlman index}}$. Thus, by Bloodgood's rule, the concentration of return sludge would be 4,000 ppm for a Mohlman index of 250, and 2,860 ppm for an index of 350. However, in 1944 Bloodgood[16] stated that return sludge concentrations might be 1.1 times the concentrations as above computed.

In 1949 Kraus[17] stated that this factor, K, might be as high as 1.2, at least for Mohlman indexes of less than 100. If the 1.2 value of K is assumed to apply to a Mohlman index of 250, the concentration of solids in the return, and hence that in the sludge reæration tank, designed as herein suggested, should be 4,800 ppm.

Bloodgood[16] also presented a nomograph to illustrate the relationship between Mohlman index, return sludge solids concentration, mixed liquor solids concentration and return sludge percentage for a K value of 1.0. Fig. 3 is similar to Bloodgood's nomograph, except it covers a wider range of values and permits readings to be made for any K value from 1.0 to 1.2. It shows that for a Mohlman index of 250 and a K value of 1.2, a return sludge capacity of 135 percent would be required if a mixed liquor solids concentration of 2,740 ppm was carried.

If the mixed liquor solids were halved to 1,370 ppm, a return sludge capacity of only about 40 percent would be needed. A mixed liquor solids concentration of 2,050 ppm would require about 75 percent return sludge capacity.

It seems doubtful that designers will find it economical to provide a return sludge capacity in excess of 100 percent. Based on a K value of 1.2, this would limit the mixed liquor solids concentration to 2,400 ppm for a Mohlman index of 250, or to 1,720 ppm for an index of 350.

Aeration Period

If the foregoing procedure is followed, the total volume of æration and sludge reæration tanks are set by (a) the B.O.D. to solids loading, (b) the maximum sludge index, and (c) the capacity of the return sludge facilities.

Both the sewage and the mixed liquor æration periods are ignored. Since most of the pollutants are quickly adsorbed by the sludge, neither of these periods is of any real significance. However, since 20 to 40 minutes may be required for completion of adsorption, and since there may be some short-circuiting in the æration tank[18], it is probably desirable to provide a mixed liquor æration period of at least 60 to 90 minutes. This offers a logical method for dividing the total æration tank volume between mixed liquor æration and sludge reæration.

In the foregoing example a 2-mg æration tank and a 75 percent return sludge capacity was indicated for a 24-mgd sewage flow if a 2-mg sludge reæration tank was also provided. Under these conditions, the theoretical mixed liquor æration period would have been (2 x 24)/(24 x 1.8), or 1.14 hours.

The design procedures herein proposed may result in the use of considerably higher rates of sludge return than are generally provided. Therefore, it may be pertinent to point out that the average sewage æration period is independent of the amount of return sludge. For example, with 100 percent return sludge the mixed liquor æration period will be just one-half of what the sewage æration period would have been with

TABLE 2 (Continued)

Plant No.	B.O.D Applied, lb per day: Per 100 lb Mixed Liq. Sol.	B.O.D Applied, lb per day: Per 1000 cf Aeration Tank Vol.	Air Used, cu ft: Per Gallon	Air Used, cu ft: Per lb B.O.D. Remov.	Return Sludge, percent by Vol.	Aeration Period, hr: Sewage Only	Aeration Period, hr: Mixed Liquor	Removal, Percent: Susp. Sol.	Removal, Percent: 5-Day B.O.D.	Reference
50	415	39.6	0.5	594	0.0	6.6	6.6	66.0	63.1	6
51	314*	40.6	0.49	544	0.0	6.43	6.43	74.4	43.5	21
52	246*	34.2	0.53	623	0.0	7.9	7.9	75.4	49.1	21
53	271*	41.0	0.59	577	0.0	7.45	7.45	80.2	45.1	21
54	126	41.0	0.68	1060	24.0	4.81	3.88	52.3	58.4	24
55	167	41.6	0.47	975	36.3	4.67	3.42	43.4	44.6	24
56	465	105.0	0.49	595	10.6	2.45	2.3	73	58	3
57	162	87.0	0.33	477	18.0	1.9	1.6	83	76	3
58	149	92.0	0.34	606	7.0	1.7	1.6	66	64	3
59	276*	14.3	0.59	1436	0.0	8.2	8.2	62.6	71.8	22
60	167	39.5	0.45	450	17.8	5.69	4.88	85.5	76.8	23
61	177	69.3	0.43	453	30.5	3.34	2.56	86.8	71.1	23
62	91	33.0	0.41	473	28.1	6.16	4.82	84.5	76.5	23
63	141	55.7	0.40	608	27.3	2.99	2.35	81.8	71.0	23
64	264	60.2	0.38	615	16.0	2.64	2.28	85.2	69.8	23
65	168	52.8	0.39	590	28.5	3.21	2.5	74.4	76.7	25

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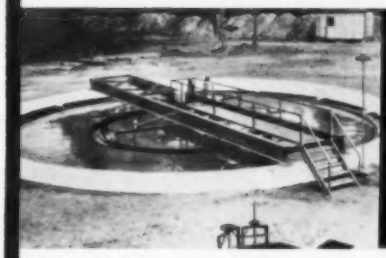

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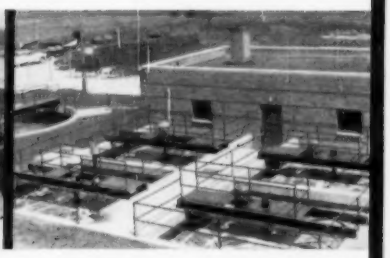

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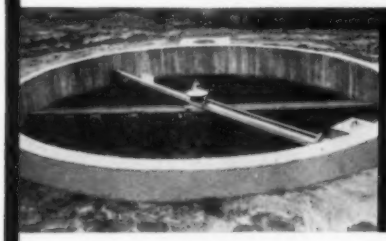

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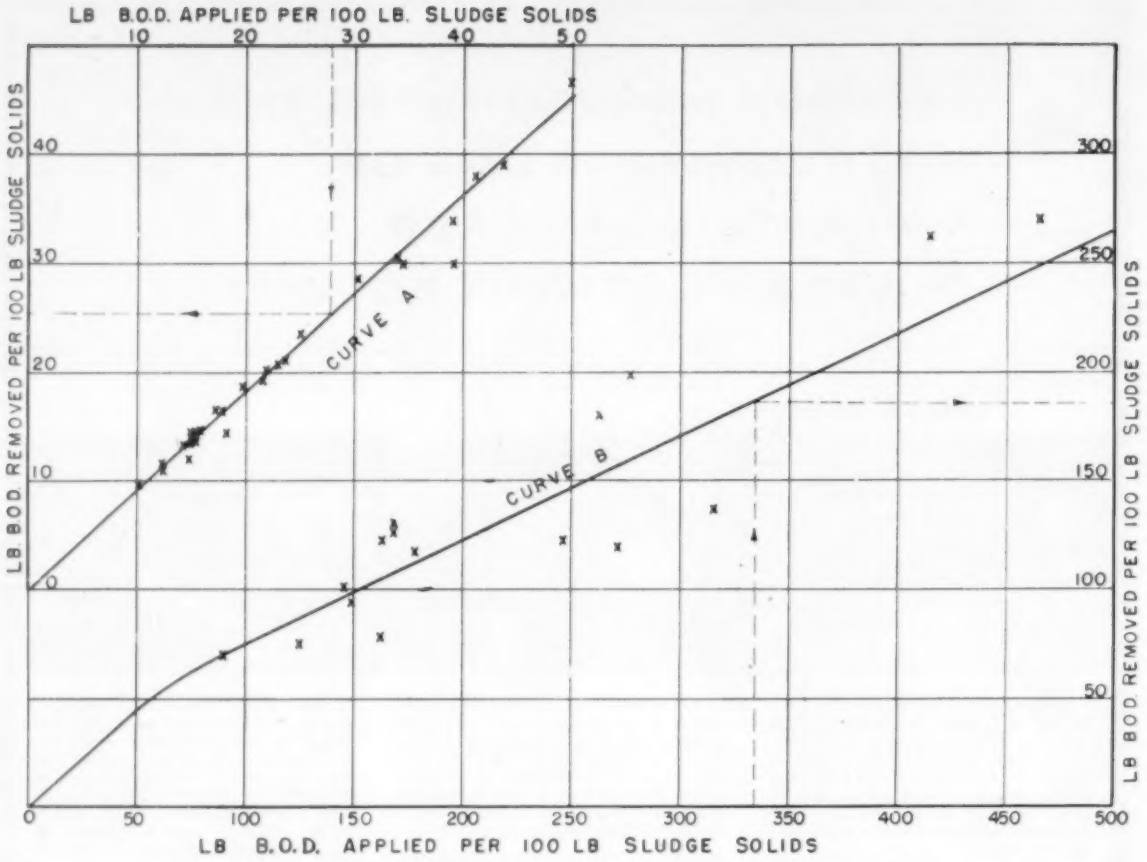

Fig. 1—RELATIONSHIP between B.O.D. loading and B.O.D. removal (see text for explanation)

no return at all. However, on the average, all of the sewage would pass through the æration tank twice, instead of once, so the effective sewage æration period is unchanged.

As long as the mixed liquor æration period is long enough to permit substantially complete clarification, any further oxidation of soluble material can be accomplished just as well on the second pass through the ærator as on the first. It is generally accepted that recirculation (at least up to a ratio of 1 or 2) greatly improves the removal of B.O.D. by trickling filters. There is no reason why it should not have a similar effect in the activated sludge process.

The National Research Council[11], Fair and Thomas[4], Smith[20] and others have proposed loading parameters that were equivalent to the B.O.D. to solids loading proposed in this paper, divided by the æration period. Fair and Thomas used the sewage æration period; Smith used the mixed liquor æration period.

Both of these conceptions are erroneous because they fail to consider the fact that the sludge solids are retained

Given:

Sewage flow, 24 mgd
B.O.D. of settled sewage, 200 ppm
B.O.D. loading, 35 lb per day per 100 lb of sludge solids

Calculations:

Applied B.O.D. = 24 x 8.34 x 200 = 40,000 lb per day
Sludge solids required = 40,000 x 100/35 = 114,300 lb

Possible designs:

Example number	1	2	3
(a) Sludge reaeration tank vol., mg	0	0	2
(b) Mixed liquor aeration tank vol., mg	5	10	2
(c) Sludge reaeration solids conc., ppm	....	....	4,800
(d) Mixed liquor solids conc., ppm	2,740	1,370	2,050
(e) Total reaeration sludge solids, lb (a x c x 8.34)	0	0	80,100
(f) Total mixed liquor sludge solids, lb (b x d x 8.34)	114,300	114,300	34,200
(g) Total sludge solids, lb (e + f)	114,300	114,300	114,300
(h) Combined aeration volume, cu ft per lb of B.O.D. 1,000,000 (at b) /40,000 x 7.49)	16.7	33.4	13.4

Fig. 2—ILLUSTRATIVE examples of how logical design affects aeration volume.

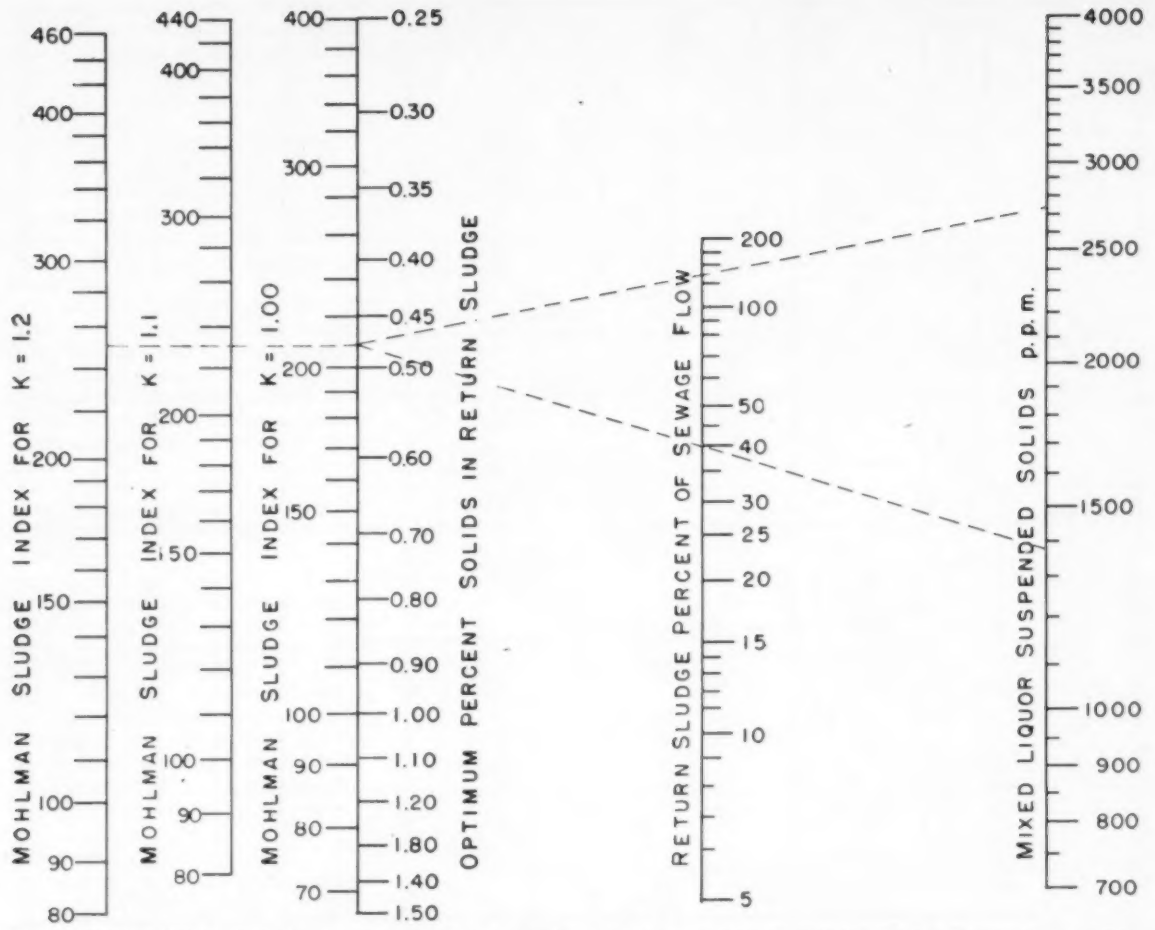
MOHLMAN SLUDGE INDEX FOR K = 1.2
MOHLMAN SLUDGE INDEX FOR K = 1.1
MOHLMAN SLUDGE INDEX FOR K = 1.00
OPTIMUM PERCENT SOLIDS IN RETURN SLUDGE
RETURN SLUDGE PERCENT OF SEWAGE FLOW
MIXED LIQUOR SUSPENDED SOLIDS p.p.m.

Fig. 3—NOMOGRAPH for determining optimum solids content and percent of return sludge from Mohlman index and mixed liquor solids concentration

in the plant through several cycles or even days. During all of that time they are undergoing oxidation. The important thing is to retain the solids in the æration system long enough to permit oxidation to balance adsorption. The sludge retention period is governed primarily by the B.O.D. to solids loading, and is independent of either the sewage or mixed liquor æration period.

Obviously, high return sludge rates increase the mixed liquor flow. However, this should not necessitate the use of larger final settlers if they are so arranged that sludge is withdrawn from a point directly below the tank inlet. However, if the point of sludge withdrawal is remote from the inlet, as in Gould's design[19], the procedure recommended herein will necessitate the use of larger final sedimentation units.

Sludge Reaeration

In the foregoing procedure the concentration of solids in the sludge reæration tank, and hence its volume, is primarily dependent upon the maximum Mohlman index selected for design. Obviously, the normal index will be lower and so the operator could frequently operate with higher solids.

Such a practice would result in building up a higher total sludge inventory and reducing the B.O.D. to solids loading. That condition should be avoided. As will be shown, it increases air requirements. It might also create a sludge disposal problem when the index again rose and the excess inventory of sludge had to be dumped over a short period of time. Such a condition could be avoided by continuously operating the return sludge facilities at their maximum capacity, but in a large plant such a procedure might be wasteful of power.

Therefore, if sludge reæration is to be used, provision should be made for introducing variable amounts of settled sewage, digester supernatant, or both, directly to the reæration tank as required.

Such an arrangement also is advantageous in compensating for the unavoidable variations in total B.O.D. load imposed on the plant. It was noted previously that the condition of the sludge, as measured by the Mohlman index, varies over wide limits from day to day at many conventional plants.

Sludge reæration with flexible provision for introduction of nutrients, either sewage or digester liquor, gives the skilled operator a convenient means of controlling such variations. This indicates the superiority of "step æration" as patented by Gould[3], the patented Kraus process[5], or the unpatented Hatfield process over the old-fashioned fixed capacity separate sludge reæration tanks formerly used.

From the viewpoint of construction costs, the principal advantages of sludge reæration are a saving in total æration tank volume and a probable

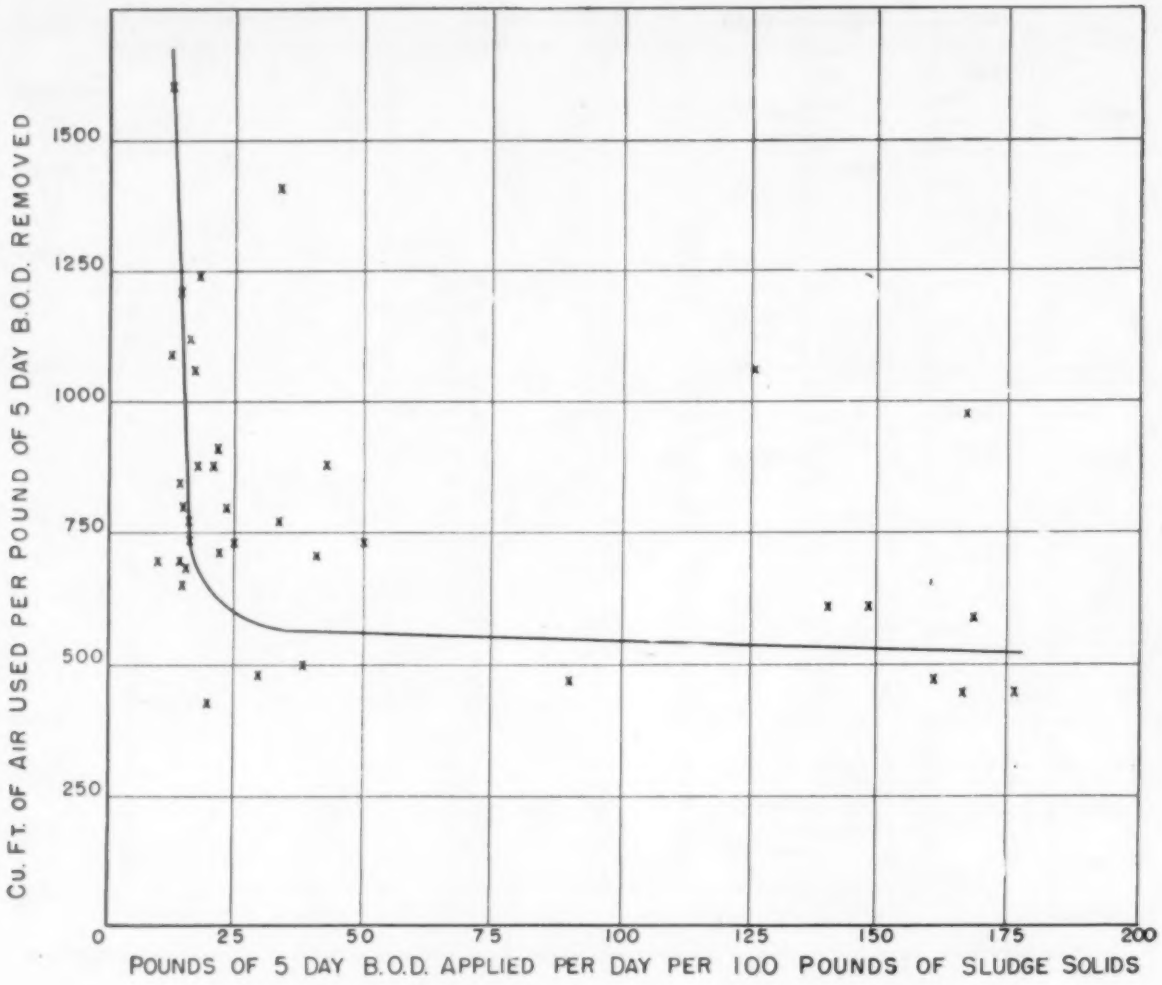

Fig. 4—CORRELATION between B.O.D. to solids loading and air consumption per pound of B.O.D. removed

reduction in the required capacity of return sludge facilities.

The disadvantages are the greater complexity of plant piping, and possibly a multiplicity of æration devices or arrangements. (For example, tapered æration may be advantageous in mixed liquor æration, but is of doubtful value in sludge reæration.) These disadvantages are always present.

The advantages become increasingly important when treating high B.O.D. wastes or when a low B.O.D. to solids loading is to be used.

Air Requirements

In diffused air plants, the air is used primarily to (a) mix the contents of the ærator, thus promoting flocculation and preventing sedimentation, and (b) supply the oxygen required for biological oxidation. Since the primary purpose of the activated sludge process is the reduction of oxygen demand, it is logical to relate air supply to B.O.D. removal rather than to volume of sewage. This was done in the newer "Ten State Standards"[2], and in several of the equipment manufacturers' criteria.

Tables 1 and 2 show average air consumption to range from 435 to 1,600 cubic feet per pound of B.O.D. removed. Although there are numerous reasons for this wide range in air requirements, it is believed that one of the major causes is the variation in B.O.D. to sludge solids loading.

In Fig. 4 the air used per pound of B.O.D. removed is plotted against the B.O.D. to solids loading. It will be noted that the air consumption was relatively constant as long as the B.O.D. loading exceeded 35 pounds per day per 100 pounds of sludge solids. It increased rapidly, however, when the loading fell much below 25 pounds.

To understand why such is the case, it is necessary to recall that most of the sewage B.O.D. is quickly adsorbed by the sludge and that it is the subsequent oxidation of the adsorbed material that consumes the oxygen. At B.O.D. loadings of 35 to 50 pounds per day per 100 pounds of sludge solids, oxidation is just barely keeping pace with adsorption. Therefore, a relatively constant relationship between B.O.D. removal and air consumption is to be expected.

However, at materially lower B.O.D. to solids loadings a considerable portion of the sludge is destroyed by "wet combustion." Furthermore, a low B.O.D. to solids loading favors nitrification. Both nitrification and wet combustion require additional oxygen, so air usage per pound of B.O.D. removed from the sewage increases.

At the high B.O.D. to solids load-

ings used in modified æration processes, oxidation lags behind absorption and sludge is retained in the plant such a short time that one might expect air consumption per pound of B.O.D. removed to drop more than is indicated by Figure 4. Possibly additional data on modified æration would give a different picture. Or, possibly, the decreased efficiency of the only partially activated sludge offsets much of the expected saving in air.

At any event, it is obvious that the capacity of the æration system provided for any activated sludge plant should be based on the B.O.D. to solids loading as well as on the total B.O.D. input. Since sludge reæration makes possible a reduction in total æration tank capacity, and hence in volume of liquor or sludge that must be mixed and agitated, it should result in some slight saving in air requirements.

In view of the many variables and unknowns involved in sewage treatment design, however, this possible saving is believed to be too theoretical to warrant consideration by the designer. The air requirements of a plant designed in accordance with the procedures herein suggested are believed to be practically the same regardless of whether sludge reæration is provided or not.

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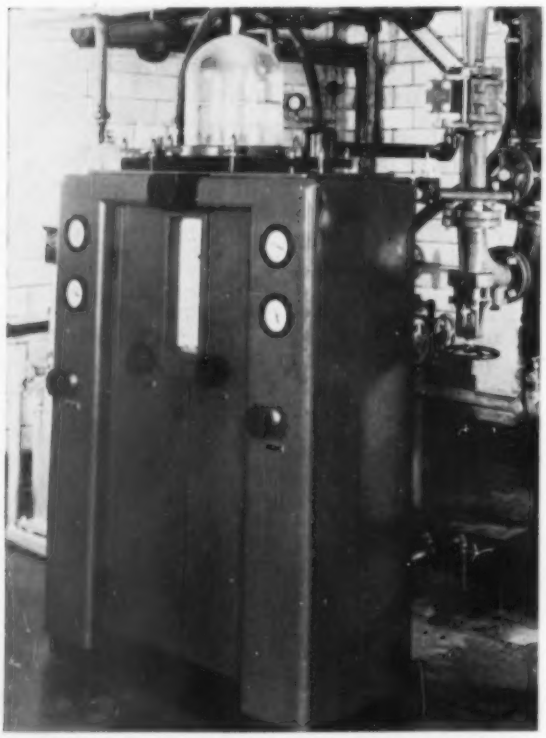

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Sewage Chlorination in Review

by WERNER N. GRUNE

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CHLORINE and various chlorine products constitute one of the most versatile and powerful tools endowed the sanitary engineer, plant superintendent or operator. The application of chlorine has steadily increased. In 1930 Gascoigne[1] listed 50 sewage plants in the U.S. employing chlorine for odor control. A 1946 survey[2] of 5400 sewage plants showed 1320 to be using chlorine for one purpose or another. The number has grown constantly. Chlorination has been accepted as an integral part of modern sewage treatment practice.

There is almost no limit to the purposes for which chlorine, or its commercially available derivatives, may be applied for some specific use in sewage treatment. The multiplicity of its uses include:

1. Up-sewer chlorination to prevent disintegration of masonry structures.
2. Control of septicity and odors along trunk sewers and in treatment plants.
3. Improving the removal of settleable solids.
4. Reducing biochemical oxygen demand.
5. Increasing efficiency of filter beds.
6. Preventing filter ponding and fly control.
7. Controlling Imhoff tank foaming.
8. Controlling activated sludge bulking.
9. Improving clarification with chemical precipitation.
10. Improving sludge digestion and elutriation.
11. Disinfecting effluent prior to discharge.
12. Retarding putrefaction in the receiving watercourse.

Since chlorine is a strong oxidizing agent, its action is basically very similar in all these applications. The quality of raw sewage, type of treatment and desired degree of final effluent purification must be considered in effective chlorination; it should be planned as an integral part of the treatment.

Chlorination Chemistry

Chlorine, a greenish-yellow gas, is one of the most active elements. It is more active than oxygen and is therefore not found free in nature. Chlorine having a molecular weight of 71 is 2.5 times as heavy as air. It can be liquefied at about 65°F and 250 psi and is commercially available as a 99.99% pure liquid. In liquid form, chlorine is easily shipped and handled under pressure in cylinders and tanks, usually under a pressure of 100-150 psi. As the gas is withdrawn from a container, more liquid chlorine reverts to its gaseous state. Chlorine will dissolve in water to the extent of 9500 ppm. at 50°F. This solubility decreases to 7000 ppm. at 68°F, 5000 ppm. at 92°F and only 4500 ppm. at 104°F.

Safety precautions are of utmost importance when chlorine is handled. To illustrate, the toxicity of this gas is shown in Table 1 (after Moore[3]).

Other forms of chlorine and chlorinated organic compounds to be discussed later are enumerated here for identification.

Sodium and Calcium Hypochlorite.....NaOCl and $Ca(OCl)_2$
Ammonia-chloramine compounds
Monochloramine .....NH_2Cl
Dichloramine .....$NHCl_2$
Nitrogen trichloride .....NCl_3
Chloroform .....$CHCl_3$
Dichloropropane .....$C_3H_6Cl_2$
Orthodichlorobenzene (Paradichlorobenzene) .....$C_6H_4Cl_2$
"Chloroben" (an emulsion of chlorinated hydrocarbons, principally orthodichlorobenzene)
Chlorophenol .....$C_6H_4OH\ Cl$
Trichlorophenol .....$C_6H_2OH\ Cl_3$
Sodium pentachlorophenate ("Santobrite") .....$C_6Cl_5\ O\ Na$
D D T .....$C_8H_7\ Cl_5$
Chlordane .....$C_{10}\ H_6\ Cl_8$

Some chlorinated aliphatic hydrocarbons and aromatic organic chlorine compounds may possess desirable characteristics, such as longer persistency in a sewer line, because they release chlorine more slowly.

"Available Chlorine"

To compare the amount of active chlorine, varying considerably between the many compounds, the phrase "percentage of available chlorine" was chosen on the basis of the oxidizing power of the compound. This simply means the oxidizing capacity equivalency on a mol basis of chlorine. To illustrate, the "available chlorine" in $Ca(OCl)_2$ is 99.2 per cent by weight, while in hypochlorous acid it is 135.4 per cent. The equivalent mol weight of the compound must be compared with the oxidizing power of a chlorine mol weight, or 71.

The term "available chlorine" therefore refers to the oxidizing power of any substance compared to that of one mol of Cl_2 regardless of whether it contains chlorine or not. It now follows that one may speak of the "available chlorine" of any oxidizing agent, such as $KMnO_4$, H_2O_2 or O_3. An excellent table, showing the per cent by weight of chlorine actually present

Table 1
Toxicological Effects of Chlorine

	ppm. by volume, in air
Least detectable by odor	about 3.5
Produces throat irritation	15
Produces coughing	30
Dangerous for 30-minute exposure	40 - 60
Rapidly fatal	1000

and "available" according to oxidizing power, was presented by Moore[3].

Chlorine-Water Reaction

When gaseous chlorine dissolves to form a dilute aqueous solution the initial products of the reaction are hypochlorous acid, hydrogen and chlorine ions:

$Cl_2 + H_2O \rightleftarrows HOCl + H^+ + Cl^-$.

This reaction is almost instantaneous even at temperatures as low as 32°F. Moore[3] states that when the pH of water exceeds 3.0, and for total chlorine concentrations less than 1000 ppm., no measurable quantity of Cl_2 exists in the solution; all chlorine being in the form of HOCl.

The hypochlorous acid dissociates instantaneously according to the reversible reaction: $HOCl \rightleftarrows H^+ + OCl^-$. The exact distribution of hypochlorous acid or "free chlorine" and hypochlorite ion, OCl—, is governed by the pH value of the water. It was established[4] that, at a pH = 5 or below, practically all the free chlorine is present as HOCl, whereas above pH = 10 practically all of it exists as OCl^-. Notice that pH is of real significance in water disinfection, since HOCl and OCl^- differ greatly in killing power, HOCl being approximately 300 times as effective as OCl^-.

Chloramines

Free chlorine reacts with organic substances, especially with ammonia and the many complex ammonia derivatives, to produce chloramines. They have properties similar to hypochlorous acid and respond to the orthotolidine and starch-iodide tests with some success. But whether the responses by the compounds to these tests can be correlated with their disinfecting efficiency is still difficult to predict. Some chloramines hardly respond to these tests but appear to be good bactericidal agents.

It is generally accepted that three chloramines are formed in the following manner:

monochloramine

$NH_3 + HOCl \rightarrow NH_2Cl + H_2O$

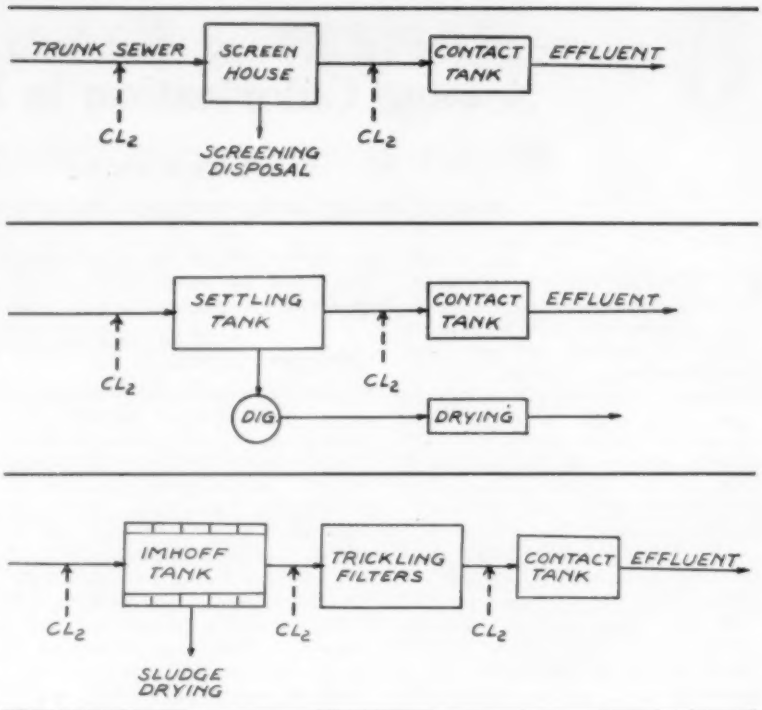
dichloramine

$NH_2Cl + HOCl \rightarrow NHCl_2 + H_2O$

nitrogen trichloride

$NHCl_2 + HOCl \rightarrow NCl_3 + H_2O$

Earlier work[5] with much higher concentrations of chlorine than those ordinarily employed showed that monochloramine only is formed at a pH above 8.5, that mixtures of mono- and dichloramine are present in the pH 8.5 to 5.0 range, that dichloramine only exists between pH 5.0 to 4.4 and that below this pH value nitrogen trichloride appears.



SCHEME of chlorine application in treatment plants

Fig. 1—(Top) Screening plant, no treatment

Fig. 2—(Center) Primary plant, partial treatment

Fig. 3—(Bottom) Imhoff tank—trickling filter plant

More recently, studies carried out at the Laboratories of Sanitary Engineering at Harvard University employed ultra-violet spectroscopy for differentiation between chloramines in solution. Table 2 presented by Moore[3] shows distribution of chloramines at various pH values for an average weight ratio of total chlorine to ammonia-nitrogen of 5 to 1, at a temperature of 77°F.

The disinfecting efficiency of chloramine solutions are dependent on the ratio of the different chloramines present, which is governed by the pH.

Sewage Chlorination

The chemistry of chlorination pertaining to water is much simpler and the reactions less complex than when dealing with the highly variable medium of sewage. Although sewage is 99.9% water, the additional 0.1% or 1000 ppm., represents large amounts of substances that readily react with chlorine.

When chlorine is added to sewage, the amounts of free available chlorine disappear quickly, and the active form of chlorine will be present as chloramines. A major portion of the chemical will have attached itself to the many organic compounds, including cell enzymes, which account for the large chlorine demand. The many varieties of chloramine compounds formed, each of different disinfection power, present a problem of analysis, since both orthotolidine and starch-iodide residuals are difficult to interpret as to disinfecting quality. A residual of 0.5 ppm. after 15 minutes may represent different disinfecting powers in different sewages, since the chlorine compounds tested are probably not of the same composition. This is one reason why specification of a chlorine residual after a given contact period is a poor measure of sterilizing effects, as pointed out by Eliassen et al[6] who tried to achieve correlation between chemical dosage and bacteriological results.

Typical Points of Application

There probably are as many different points of chlorine application as there are different types of treatment plants. Some of the more typical points used in actual operating practice are shown in Figs. 1-6. The first point in each diagram refers either to

Table 2

Chloramine Distribution at Various pH Values

pH	Percentage of Chlorine present as Monochloramine	Dichloramine
5	16	84
6	38	62
7	65	35
8	85	15
9	94	6

an application on the sewer line or trunk sewer, at a pumping station, or as prechlorination at the plant. As pointed out by Griffin[7] it has become common practice to use terms such as up-sewer chlorination, pre- and post chlorination, plant chlorination, and aero-chlorination. These terms refer mainly to the position of chlorination but generally do not explain the reason for the chlorine application.

Disinfection

The primary purpose of sewage disinfection is to protect sources of public water supply, to prevent bacterial contamination of bathing places, and to safeguard shellfish propagation beds.

Sometimes chlorine is used to reduce the bacterial density of raw sewage. Wyckoff[8] studied the rate of coliform kill in plant-scale chlorination of raw sewage, and showed that an initial residual of less than 0.5 ppm. produced only a negligible bacterial kill in one minute. With initial residuals exceeding 0.5 ppm. and up to 6.5 ppm.[6] (the maximum studied), the kill after one minute contact was 80 per cent and usually over 90 per cent. After five minutes of contact, and for residuals of 0.5-6.5 ppm., the median bacterial kill exceeded 99 per cent. Little additional kill could be accomplished during 15 and 30 minutes and no further survival number decrease at 60 minutes of contact were noted. These results indicate that a 1-15 minutes contact period is most economical for raw sewage chlorination.

Due to the difficulty in securing penetration of grosser solids when raw sewage is chlorinated, more efficient disinfection is obtained by mechnical agitation to break up the solids prior to chlorination. Screened sewage has been disinfected by chlorine dosages ranging from 5-15 ppm. as a necessary stop-gap measure until towns could proceed with the construction of a treatment plant.

In 1945 Griffin[9] related the effects of heavy doses of chlorine on raw screened sewage and showed a "breakpoint" at a chlorine application of 250 ppm. It is doubtful that such extremely large doses of chlorine will ever be used in the municipal field.

Effluent chlorination usually is applied for the specific purpose of reducing B.O.D. and reducing the bacterial load on the receiving stream. Unfortunately, most bacterial results reported show only the percentage removed within the plant. It cannot be overemphasized that it is the number of bacteria remaining in the effluent which determines the quality of the receiving stream and not the percentage of bacterial reduction through the plant. Symons[10] reported that a residual of 0.1 ppm. after 15 minutes contact produced the desired kill at Buffalo, N. Y.

Dosage and Bacterial Density

Eliassen et al[6] recognized the value of a control test for the sewage treatment plant operator which would indicate the relationship between a stipulated bacterial density in the effluent and the necessary chlorine dosage. In many plants the chlorine dosage is fixed in proportion to the flow. Consequently, variations in chlorine demand or residual chlorine are not considered. It was reported[6] that MPN of coliform bacteria remaining in the sewage after ten minutes contact with chlorine bear no direct relation to the initial dosage.

Experimental evidence showed that with thorough initial mixing, MPN values per 100 ml. would be 300 or less 50 per cent of the time when a residual of 0.55 ppm. after 10 minutes contact was maintained. In contrast, when no initial mixing was provided, it was necessary to maintain a 1.1 ppm. residual to achieve the same results. The raw sewage averaged 120 ppm. B.O.D., with 5 ppm. of chlorine demand. A stipulated MPN criterion of 300 per 100 ml, as frequently cited by stream pollution authorities, was used for the purpose of illustration. These findings provided the clue to three important aspects of sewage disinfection by chlorination:

1. A fixed chlorine dosage in ppm. is not satisfactory when a stipulated MPN of coliform bacteria in the effluent must be achieved.
2. The rational method of controlling chlorination is to maintain a fixed chlorine residual in the sewage after a specified contact period to achieve a stipulated MPN in the effluent a certain per cent of the time.
3. There is a striking advantage due to initial mixing prior to the contact period. Especially improved efficiencies are obtained with dosages in excess of 140 per cent of the chlorine demand.

The type of mixing whether slow or rapid is not important, but the low velocity at the beginning of chlorine contact chambers generally is insufficient. Disinfection results will be improved by using proper mixing devices to secure a thorough dispersion of chlorine and to permit its uniform action throughout the mass of sewage. Mixing also will accomplish a marked saving in the cost of chlorine.

State Board of Health requirements range from 0.2 ppm. chlorine residual after 5 minutes contact, to 1.0 ppm. after 30 minutes. The average appears to be 0.5 ppm. after 15 minutes. These regulations recognize that the chlorine demand of sewage must be satisfied before complete disinfection can be obtained. A large part of the demand is due to the organic content of sewage, to the presence of H_2S, and the bacteria and slimes responsible for the formation of this odorous gas.

In Table 3, Enslow[7] gives the average values which will produce a residual of 0.2 ppm. after a 10-15 minute contact period.

As expected, settled sewage, effluents from trickling filters, plants using the activated sludge process, and sand filters require proportionately lower dosages depending upon the degree of purification secured by the plant.

Odor Control

The use of chlorine for odor control stands second only to disinfection. Long, flat-grade trunk lines, sewer slimes and sludge deposits will result in sewage putrefaction and give rise to odor nuisances and corrosion problems. Elimination of foul odors from sewer systems and treatment works throughout the year is increasingly difficult. With the rapid expansion of population centers and modern highways into the outlying districts, the problem has become more acute in recent years.

Hydrogen sulfide odors are the cause of most odor complaints. These odors are checked by chlorine in two ways. First, as a powerful oxidizing

agent chlorine kills bacteria, oxidizes sulfides and raises the O-R potential. Biological activity and bacterial decomposition both of organic and inorganic sulfur-containing compounds present in normal sewage is retarded. *Sporovibrio desulfuricans* are responsible for the biochemical reduction of sulfates to produce H_2S. Chlorination, by effecting a mild oxidizing condition in the sewage, permits it to accumulate a little dissolved oxygen; then the sewage continues in an oxidized state, preventing the reappearance of sulfides for some distance downstream.

A negative oxidation-reduction (O-R) potential is measured when H_2S is produced, and indicates septic conditions. With sufficient chlorine added to sewage, a positive O-R potential is established. Biological sewage treatment usually operates well as long as the potentials are on the oxidative or positive side. Maintenance of the positive potential due to fresh sewage conditions, cleanliness, and ventilation in sewers, prevents the development of reducing types of bacteria and the production of H_2S.

Sewer Slimes

Secondly, chlorination prevents the production of H_2S from sewer slimes. Pomeroy[11] and Heukelekian[12] clearly demonstrated that sulfides are generated only by slimes on submerged surfaces, or in sludge deposits along sewer bottoms, in free flowing sewers. It has been found that the amount of sulfide production arising from the sewage in filled sewers is usually negligible. Except under conditions of extreme reduction, sulfate concentrations are not expected to have much effect on the rate of sulfide production in sewers.

Beardsley[14] calls the slimes on the sewer surfaces "zones of rapid biochemical change" and regards the chemical transformations brought about due to a combined effort of bacteria, fungi, protozoa, worms, and insects in the slime. Slime deposition is most favorable where the surface of the flowing stream meets the wall. Longitudinal velocity here is negligible and the action of surface ripples favors deposition of suspended material from the stream. The growth of reducing organisms in sewer slimes is favored by warm weather, 80°F being optimum temperature. Sewage in contact with such growths becomes charged with sulfides.

With the realization that sulfides usually are not produced in the sewage stream but in the slimes along sewer walls, sufficient chlorine must be added to carry a sterilizing concentration through the section to be treated.

Table 3

Required Chlorine Dosages for Disinfection

	Chlorine, ppm.
Crude sewage	
Fresh to stale	6 - 12
Septic	12 - 25
Settled sewage	
Fresh to stale	5 - 10
Septic	12 - 40
Chemical Precipitation effluent	3 - 6
Trickling Filter effluent	
Normal	3 - 5
Poor	5 - 10
Activated Sludge effluent	
Normal	2 - 4
Poor	5 - 8
Intermittent Sand Filter effluent	
Normal	1 - 3
Poor	3 - 5

Continuous dosage at such high rates generally is uneconomical. Intermittent chlorination is the better method, for once the slimes are killed considerable time may pass before new developments of active microbial cultures develop again.

Chlorine and Hydrogen Sulfide

The reduction of chlorine by hydrogen sulfide may be indicated by the following reaction:

$$H_2S + Cl_2 \rightarrow 2\ HCl + S$$

This shows that for every ppm. of H_2S destroyed, 2.2 ppm. of chlorine must theoretically react in a pure water solution. In the presence of many other reducing agents that consume chlorine in sewage, a lowered efficiency of sulfide destruction is expected.

Pomeroy[11] found the chlorine-sulfide ratio to vary from 3 to 9 for numerous septic sewage samples from the Los Angeles County Sanitary Districts. Sulfides exert a high and almost instantaneous chlorine demand. One sulfur atom undergoing complete oxidation from the sulfide to the sulfate condition, destroys the bactericidal power of 8 chlorine atoms, the ratio of equivalence by weight being almost nine to one. In alkaline solutions, low concentrations of chlorine do not quantitatively oxidize sulfides to sulfates. With a pH above 8 the ratio of chlorine reduced to sulfide oxidized may fall as low as 5 to 1.

The ratio of increase in chlorine demand of sewage to the increase in total sulfides is likely to be 15 to 1, or even 25 to 1, when sulfides are generated by the action of slimes. The ratio is determined for each case by the character of sewage and slime growth.

In practical application, from 6 to 15 lbs. of chlorine are necessary for each pound of sulfide eliminated. The higher values are due to less efficient mixing in the sewer (as compared to bottle tests), since a proportion of the chlorine is used up in side reactions. Where sulfide tests can be satisfactorily carried out, sufficient chlorine to keep the sulfide concentration below 1.0 ppm. should provide effective odor control.

In many cases the sulfides are destroyed after they have formed, instead of attempting to prevent their generation. Following this principle rigorously would require an excessive number of chlorinators. Actual practice requires adoption of a compromise, locating the chlorinators where they will destroy sulfides entering the trunk sewer and also, by using moderate excess dosages, preventing sulfide formation for some distance downstream. The main difficulty in odor control is that no O.T. residual is produced. This difficulty can be overcome by means of a cell connected to a chlorinator through a series of relays. When the O-R potential drops below a predetermined point, the cell impulse actuates the chlorinator which in turn applies more chlorine. This is known as the "potential chlorination" system used by Fort Wayne, Indiana, for many years[13].

Beardsley[14] stated that elimination of slimes by disinfectants added to the sewage never can prove economically sound since many of the slime producers are capsulated bacteria. He therefore advocated surface treatment with bactericidal compounds. After a thorough cleaning of sewer walls, a

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PLANTS AT WICHITA, KANSAS
AND DENVER CITY, TEXAS

10 per cent emulsion of Chloroben applied to the cleaned sewers inhibited the growth of slimes for one year. Rapid recovery of sulfide production had been noted when treatment with chlorine was discontinued and "the drop in sulfide production was followed by a rebound to high output in 3 to 4 days." The slow but steady bactericidal effect of chlorinated hydro-carbons has been considered to cause reductions of hydrogen sulfide. Laboratory studies[11] indicated some success with chlorophenol, Chloroben, chlorinated propanes, and sodium pentachlorophenate. Pentachlorophenate, trichlorophenol and chloropropanes showed greatest promise. Brown[15] added Chloroben at the upper end of large sewers and claimed reductions of sulfide concentration up to 92 per cent. Initial concentrations of 15-17 ppm. of H_2S in the sewer atmosphere were reduced to less than 2 ppm. when the equivalent of 1-2 ppm. of Chloroben were added in the outfall sewer. Further success in H_2S odor reduction by the routine application of 2 ppm. of chlorinated hydrocarbons was reported at Oklahoma City[16].

Eliassen[17] found that H_2S production by sulfate reduction cannot be controlled by small dosages of Chloroben but the organism responsible for the breakdown in sewer slimes and sludge deposits, *Sporovibrio desulfuricans*, must be removed. H_2S formation by the decomposition of sulfur-containing organic compounds, i.e. proteins and amino acids, and by normal sewage organisms, such as the coliform group, can be effectively retarded by the addition of about 1 ppm. of Chloroben. Thus the sewage is kept in a relatively fresh state for a long enough period to permit passage through a sewer system. Concentrations in excess of 1 ppm. do not seem to improve further inhibition of sulfides. It should be stated that any inhibitory effect is nullified in the presence of low O-R potentials, (–200 to –300 mv), indicative of great activity of sulfate-reducing organisms and septic conditions.

Hood[18] at Ridgewood, N. J., demonstrated the successful control of sulfides by copper sulfate. An average application of 2 lbs. per manhole, and of 2-3 lbs. through each house connection, has for almost two decades destroyed roots causing sewer stoppages and sludge deposits. Freedom from roots and other obstructions in house connections and street mains keeps sewage "fresh" and prevents H_2S production when entering flat-graded trunk lines, poorly maintained sewers and the sewage treatment plant. Hood[18] feels that the chlorinated hydrocarbon compounds, capable of suppressing bacterial activity for a period subsequent to their application, are "merely pallative rather than curative measures."

Preventing Masonry Disintegration

Closely allied with the use of chlorine for odor control is its function of preventing disintegration of masonry and concrete sewers, deterioration of paints and coatings, and the prevention or mitigation of corrosion on steel structures.

Concrete is not directly attacked by H_2S, but this gas is rapidly oxidized, first to sulfurous acid and finally into sulfuric acid. The latter attacks concrete, spalls porous acid-proof cements causing disintegration of the underlying mortar, makes asphalt coatings worthless, and sulfur-silica mixtures used for jointing have not always performed satisfactorily. Generally only 5 to 10 per cent of the equilibrium concentration of H_2S is found in the sewer air indicating a rapid conversion of H_2S to H_2SO_4 along the exposed sewer walls. Moisture clinging to the walls and a sufficient supply of H_2S provides a suitable environment for *Thiobacillus* to efficiently catalyze the formation of H_2SO_4.

H_2S production by slimes and from deposited sludges in the sewer increases with increasing temperature, increasing sewage strength, decreasing pH and decreasing velocity of sewage flow. It was estimated[11] that average dissolved sulfide concentrations should not exceed 0.1 ppm., to prolong the life of a concrete sewer almost indefinitely from acid corrosion.

When up-sewer chlorination is practiced for odor control, which means slime and consequent sulfide control, the chlorine requirements will generally be from 6 to 15 ppm. for each ppm. of sulfide. The necessary amount of chlorine is less than that required to satisfy the chlorine demand. When a number of concrete sewers had deteriorated from sulfide attack, Kennedy[19] applied a concentration of 1 ppm. of Chloroben after the slimes were removed mechanically and with chlorine. Chloroben treatment was successful when added to give maximum contact time. It was estimated that considerable savings were effected by the substitution of Chloroben over chlorine.

Chlorination for Grease Removal

The many adverse effects caused by grease and scum in sewage include: blinding of screens, accumulation along walls, destruction of paint on steel structures, interference with Imhoff tank operation, interference with aeration, clogging of filter beds, and sludge digestion problems.

Troublesome grease emulsions in sewage or industrial wastes may be broken up by the addition of chlorine. It was found that the amount of scum removed from the surface of settling tanks can be increased by prechlorination without increasing the frequency of skimming. Faber[20] reported the use of chlorine with diffused air, a process called aerochlorination.

With prechlorination it is not necessary to chlorinate to a residual. A dosage of 2-5 ppm. of chlorine often is sufficient. It may be applied ahead of a preliminary skimming tank, settling or aeration tank. When aerochlorination is used the gas is mixed with the air supplied to the aeration tank; from 2-10 ppm. of chlorine are mixed with 0.02 to 0.20 cu. ft. of air per gallon of sewage, using 3 to 20 minutes' aeration period. The procedure was modified at Lancaster, Pa., by applying chlorine solution to the sewage ahead of the aerators.

B.O.D. Reduction by Chlorination

The purposes for which chlorine is added to reduce B.O.D. include: plant overload, due to exceeding the designed capacity; presence of industrial wastes in the sewage; or too much supernatant for the raw sewage to handle.

As early as 1927, Enslow[21] reported that B.O.D. reductions up to 62 per cent could be expected with chlorination alone and that the greater the initial B.O.D. the greater the percentage removal. Later Griffin[9] confirmed that the stronger the sewage, the greater the B.O.D. removal per pound of chlorine added. Baity[22] found that dosages of 10-15 ppm. with a 10 minute chlorine residual of 0.2-0.5 ppm., showed a B.O.D. decrease of 43 per cent and that higher chlorine dosages effected little increased oxidation. These B.O.D. reductions were permanent, since 15-day incubations showed relatively the same effect as 5-day samples.

Where plants are inadequate to protect stream quality, especially during dry periods, chlorination for B.O.D. reduction is economical and effective. Chlorinating sewage to a residual retards biological activity, often permitting sewage to be carried downstream for adequate dilution before rapid decomposition sets in. Using chlorine for relieving the load on the stream is particularly applicable for plants employing only primary treatment. It must be remembered that chlorine, though an effective adjunct.

cannot be considered a substitute for secondary treatment.

Prechlorination for reducing plant overload will reduce the B.O.D., approximately 2 ppm. for each ppm. of chlorine applied. It is generally accepted that chlorination of sewage, sufficient to produce a slight residual after 15 minutes of contact, results in 5-day B.O.D. reductions of 15-35 per cent.

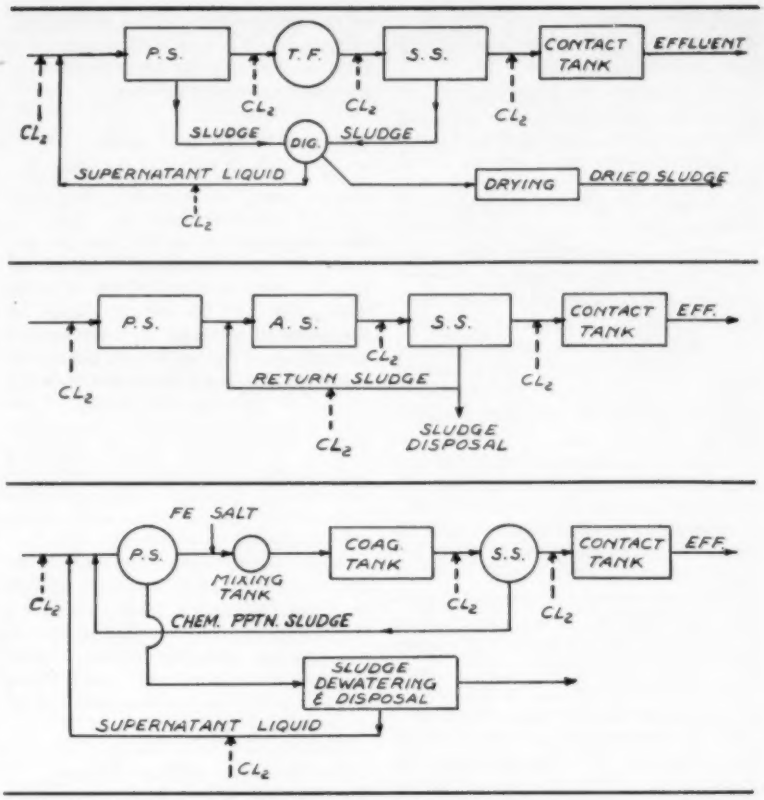
There is no decisive evidence whether the 5-day B.O.D. reductions observed result from a reduction of the *total* amount of decomposable matter, or a reduction of the *rate* of B.O.D. exertion, but recent studies by Snow[23] indicate quite well that both total amount of B.O.D. and rate of exertion account together for the observed B.O.D. reductions. The stage of decomposition of the organic matter in the sewage is pointed out as the determining factor in the amount of B.O.D. reduction that can be expected. Chlorination of fresh sewage to a trace residual after 15 minute contact period produced only 10 per cent reductions instead of the usually accepted 15-35 per cent range. To obtain reductions of 35 per cent chlorine doses as high as 100-300 ppm. had to be used. Reductions as high as 75 per cent were achieved by chlorination to the "breakpoint" but the use of such extreme amounts of chlorine would be prohibitive.

Further proof that the condition of the sewage has a great influence on the B.O.D. reduction was observed when sewage was initially incubated under aerobic conditions for one-half to two days and then chlorinated to a 15-minute residual. B.O.D. reductions of 25-40 per cent were obtained. Anaerobic incubation for one day yielded 23.6 per cent reduction of the 5-day B.O.D. compared to only 11 per cent when the sewage was fresh.

Large B.O.D. reductions also were achieved with a plain aeration period of 30 to 60 minutes preceding chlorination. The maximum overall efficiency was 44 per cent. This was obtained with 60 minutes of plain aeration followed with sufficient chlorine to produce a trace residual after 30 minutes of contact. Snow[23] suggested the combination of plain sedimentation, plain aeration and chlorination for an intermediate degree of sewage treatment.

The common practice for decreasing the load on the receiving stream is prechlorination ahead of settling. Hazeltine[24] reported that changing from postchlorination to prechlorination at the primary units produced greater B.O.D. reductions through one clarifier that was previously attained through the use of two clarifiers operating in series at Butler, Pa.

Postchlorination of the primary effluent has been used successfully, with B.O.D. reductions up to 50 per cent reported, although the reduction normally is not expected to exceed 25-35 per cent.



SCHEME of chlorine application in treatment plants

Fig. 4—(Top) Complete treatment trickling filter plant

Fig. 5—(Center) Complete treatment activated sludge plant

Fig. 6—(Bottom) Chemical precipitation and sludge dewatering

Chlorine in Secondary Treatment

At some plants, ponding or pooling of trickling filters occurs regularly in the late winter or early spring. The clogging and resultant ponding of filters may be due to several conditions, including:

1. A gelatinous organic growth of algae or fungi on the stones
2. Sewage solids not removed in primary treatment
3. Deterioration and spalding of the stones.

The trouble often is caused by algal growths forming a gelatinous slime, catching the solids coming over from settling tanks, enmeshing dust and cinders from the atmosphere, and finally resulting in the stoppage of the filter nozzles as well as ponding of the bed.

Preventing Filter Ponding

Chlorine removes the slime accumulation on nozzles and stones by virtue of its algacidal properties. The deposits slough off and are then washed out of the filter. Since clogging usually manifests itself in the upper 8 to 16 inches of the bed, these surface growths must be killed. Treatment periods should be short to prevent chlorine from penetrating too deeply into the beds.

Removal of this material can be accomplished by the application of a solution of calcium hypochlorite, or of dry hypochlorite on the filter surface if more practicable. Another control method consists of applying chlorine just ahead of the filter, as in the dosing tank. Continuous application usually is employed until the filter is clean, and following applications are practiced intermittently to maintain the clean condition of the bed. Many

operators chlorinate only at night when the sewage chlorine demand and flow are at a minimum.

The amount of hypochlorite required for the relief of filter ponding may be expected around 8-12 lbs. of available chlorine per 1,000 sq. ft. of filter area. If filter influent chlorination is used, a 1-10 ppm. residual must be maintained at the spray nozzles. Inasmuch as the effluent from primary units often is high in chlorine demand, this residual may require anywhere from 5 to 40 ppm. of chlorine. No matter which practice is followed the treatment should be repeated nightly. Several successive treatments may be required before filter ponding is relieved.

Where periodic ponding occurs, a regular chlorination program may be advisable to insure permanent relief. Chlorination is then programmed to apply a certain dose to the filter influent for a predetermined time interval, once weekly or some other convenient schedule. The required dose should be sufficient to give residuals of 1-2 ppm. at the nozzle.

At Westfield, N. Y.,[25] it was necessary to spray the filter surface directly from the chlorinator hose to correct a bad condition of filter ponding. At Butler, Pa.,[26] recirculation of heavily chlorinated final tank effluent would not relieve ponding. By holding the distributor arm in one place for about 30 minutes and then rotating the arm a few feet until the entire filter surface had been treated identically, the ponding was finally eliminated. The filter effluent generally returns to a satisfactory quality in about a week after ponding is relieved. Then the effluent often is of improved quality.

Control of Filter Flies

Preventing the growth of *Psychoda alternata*, the filter fly, is preferable to reducing this fly nuisance once the situation has gotten out of control. It is reasonable to expect that chlorination, adequate to remove some of the organic growths in the upper layer of the filter bed, will considerably minimize the breeding ground for the psychoda fly.

Chlorination for fly control is resorted to only during the fly season. The amount of chlorine required is less than that necessary to relieve ponded filters. A slight chlorine residual at the spray nozzle, resulting from a 3-10 ppm. chlorine dosage usually is effective. Chlorination should be programmed during night flows for minimum chemical cost.

There may be some relationship between the number of chlorine atoms in the compound and its insecticidal potency. DDT and Chlordane have been reported to be effective in *Psychoda alternata* control.

Activated Sludge Chlorination

As early as 1929, the activated sludge plant at Barnsley, England, showed improvement by applying bleaching powder to the raw sewage prior to sedimentation.[27] Increased benefits were obtained when chlorine was applied to the return sludge at the point of mixture with the settled sewage. In 1934 at Lima, Ohio, the return sludge was chlorinated during a period of bulking, and Smith[28,29] reported that small amounts of chlorine effectively reduced fungus growths and stopped the bulking. A relation between the required amount of chlorine and the percentage of solids in the return sludge was noticed.

Many explanations for the role of chlorine in sludge bulking control have been advanced, among these are the maintenace of aerobic action in the aeration tanks by limiting reproduction of protozoa (to maintain a suitable protozoa-bacteria ratio) or of *Sphaerotilus natans*, and a B.O.D. reduction in return sludge. There is little doubt that chlorine kills part of the biological life in the return sludge. Tapleshay[30,31] described the action of chlorine as restoring the balanced load between organic matter and biological life in the return sludge.

The proper dosage is a function of the sludge index and the dry weight of solids in the return sludge computed according to this relationship[30]:

$$S.I. \times F \times W \times 0.0000834 = \text{lbs. of } Cl_2/\text{day}$$

where: S.I. = Mohlman Sludge Index
F = Return sludge rate, m.g.d.
W = Suspended solids in return sludge, ppm.

A chart[31] covering a wide range of suspended solids and sludge index values shows that from 2-24 lbs. of chlorine per 100,000 gals. of returned sludge is required. Normally the dosage is about 5 ppm. of chlorine based on return sludge flow. The treatment never produces an O.T. residual; such a concentration would be undesirable because of excessive kill of beneficial biological life in the sludge. Tapleshay found the best point for chlorine application to be in the return sludge, allowing 2-3 minutes contact prior to mixing with primary effluent. He found it best also to keep the rate of return sludge as near a constant percentage of the flow as possible during chlorination, to practice continuous application rather than intermittent chlorination, and to make only minor adjustments of the dosage from day to day. Little reliance can be placed on chlorine demand determinations of the return sludge, the results being too variable for control purposes.

When chlorine is first applied to return sludge, a turbid plant effluent may be expected as the reaction sets in. This turbidity decreases as the index is reduced and the real improvement will be found after 3 or 4 days. The practice of chlorination for control of bulking cannot be considered as a cure-all for all cases of bulking. Physical defects such as poorly balanced mixed liquor solids' concentration, return sludge rate and air application for the B.O.D. loading are among other factors which may cause the condition.

Chlorine has been effectively employed for the cleaning of clogged diffuser plates in aeration tanks. For this purpose, chlorine is added directly into the air header or an intermittent basis, about 3-4 lbs. per hour per air header unit for a period of 2-3 hours during the day.

Chlorine is an economical method for cleaning plates. Though it will not give continuous relief, the frequency of plate removal for cleaning with acid or by burning is decreased, and treatment of the plates can proceed while the aeration tanks remain in operation.

Supernatant Liquor Chlorination

Supernatant liquor from digesters usually has an extremely high chlorine demand (10,000-30,000 ppm.), and when returned to the primary tank influent often upsets the plant due to the overload it creates.

At some plants chlorine is applied to the incoming raw sewage to minimize upsets during supernatant return. Where prechlorination is practiced, the dosage need be but slightly increased if the supernatant is returned slowly but continuously throughout the day. Another method is to return the supernatant in the early morning hours when the raw sewage has a minimum chlorine demand and the mixture is then chlorinated prior to settling. Definite dosages are difficult to state, but 20-80 ppm. of chlorine applied to the supernatant often is sufficient to reduce the load on the plant.

Foaming Control by Chlorination

Foaming may occur as the result of "wild" bacterial activity when the pH of the digester contents is above 7.0. For control, lime generally is tried first. Chlorine has often provided the answer where lime failed, especially

in foaming Imhoff tanks. The application of sufficient chlorine to sewage entering such tanks, to produce an O.T. residual, slows down such activity and decreases the evolution of gas responsible for the foaming. The application of 3-15 ppm. of chlorine usually reduces foaming and sometimes stops it completely.

Conclusion

The examples cited illustrate economic applications of sewage chlorination. It should be clear that in no case have other sewage treatment processes been supplanted by chlorination. The effectiveness and the efficiency of chlorination is limited, and it cannot be employed alone where any degree of treatment is required. But chlorination *supplements* many other processes and has found its proper place among them.

The slow action and long retention properties possessed by some of the chlorinated organic compounds eventually may answer the problem of sulfide control. Much more laboratory and field study, together with economic consideration, must await any final conclusions at this time.

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SOLIDS DISPOSAL

Outline of Modern Methods and Practices

Removal of suspended and floating matter from sewage is the principle purpose of primary sewage treatment. Disposing of these solids presents one of the major problems of sewage treatment plant operations.

The following pages of this Reference & Data Issue of *Water & Sewage Works* contains articles, data and information on this general topic. The outline below shows the broad area of topics which fall within the general subject of solids disposal.

I. . Types of Solids

A. Grit
   1. Sand
   2. Cinders
   3. Garbage
   4. Miscellaneous

B. Screenings
   1. Leaves
   2. Trash
   3. Miscellaneous

C. Skimmings
   1. Grease
   2. Soap
   3. Ground Screenings
   4. Trash
   5. Miscellaneous

D. Raw Sludge
   1. Volume
   2. Solids Content
   3. Composition

E. Digested Sludge
   1. Volume
   2. Solids Content
   3. Composition

F. Secondary Sludge (Activated or Trickling Filter Humus)
   1. Volume
   2. Solids Content
   3. Composition

II. . Solids Handling

A. Grinding Screenings

B. Conveying Grit
   1. Flight Scrapers
   2. Bucket Elevators
   3. Screw Conveyors

C. Pumping
   1. Types of Pumps
   2. Piping
   3. Metering

III. . Sludge Digestion

A. Tanks
   1. Design
      a. Floating Cover
      b. Fixed Cover
      c. Size and Capacity
      d. Heating
         (1) Internal
         (2) External Heat Exchangers
      e. Mixing
   2. Digestion Period
      a. Loadings
      b. Mixing
   3. Operation
      a. Additions
      b. Withdrawals
         (1) Supernatant Liquor
         (2) Digested Sludge
      c. Recirculation and Mixing
         (1) Mechanical
         (2) Gas
      d. Scum Problems

IV. . Sludge Dewatering

A. Chemical and Mechanical

V. . Sludge Dewatering

A. Sludge Type and Concentration
   1. Raw
   2. Digested
   3. Activated

B. Treatment
   1. Chemical
      a. Kinds of Chemical
      b. Amount of Chemical
   2. Vacuum Filtration
      a. Kind of Filter
      b. Character of Filter Cake
      c. Yield
   3. Natural Drainage
      a. Sand Beds
      b. Lagoons

VI. . Final Disposal

A. Drying
   1. Natural on Sand Beds
   2. Artificial Heat

B. Incineration
   1. Incinerator Operation
   2. Ash

C. To Land
   1. Soil Conditioner vs Sludge
   2. Fill as Ash or Sludge

D. To Sea
   1. Barging
   2. Pipe Line

SLUDGE DIGESTION AND GAS UTILIZATION

RAW SEWAGE sludge is undergoing active decomposition as it settles to the bottom of a primary sedimentation tank. This decomposition can be controlled if the sludge is removed almost immediately to a separate compartment, otherwise the sludge will float upward into the settling zone and leave the settling tank with the effluent.

Sludge Digestion

Fine screenings are practically always incinerated, but raw sludge from primary sedimentation tanks is practically always digested. In many trickling filter and activated sludge plants, the sludge from the final clarifiers is returned to the primary clarifier, or it may be pumped directly to the digesters. The former practice has less upsetting effect on digestion.

The decomposition or digestion of sludge is brought about by bacteria which function in the absence of atmospheric oxygen. These organisms are always present in sewage and begin to develop as soon as conditions become anaerobic (no dissolved oxygen). The principal bacteria are of several types working together, but the reaction involved is an anaerobic hydrolysis and oxidation of the organic matter to produce fatty (organic) acids which in turn are decomposed to produce gas consisting of carbon dioxide and methane and small amounts of hydrogen, hydrogen sulfide, and ammonia which is dissolved in the liquid. Although most of the gas is produced in the first week, further digestion is necessary to stabilize the remaining organic matter, reduce its water binding characteristics, and produce a good digested sludge, which will be black, have a slightly tarry odor, drain well, and be inocuous as fill. Thus there are two stages of digestion.

If digestion tanks are overfed in relation to capacity, or lack sufficient heat, or fail to maintain the proper pH, the acid "intermediates" production may outstrip the conversion of those acids to gas. The tanks then become sour, the pH drops, odors result, gas production decreases, digestion slows down and may stop.

Control of temperature is very important and in some cases the addition of lime has been used to raise the pH which has been lowered by the production of the organic acids. Best control is to reduce the rate of feed and to keep a check on the volatile acids, to make sure that they do not go above 2000 ppm.

Digestion Tanks

Digestion takes place in the sludge compartment of an Imhoff tank or in separate sludge digesters, where clarifiers are used for primary sedimentation. No attempt is made to heat Imhoff tanks, but the sludge compartments are usually well below ground level. Separate sludge digesters are heated (either by internal hot water coils or by external heat exchangers) to maintain approximately optimum temperature.

Generally, digester capacity of 2 to 4 cu ft is provided per capita in heated tanks. More is required in unheated tanks and where ground garbage is a factor in the quantity of sludge received. Digesters of 1 cu ft per capita have been built but scum may result with this low capacity.

Provision is made in all tanks for the addition of raw sludge, and the removal of supernatant liquor and digested sludge, the former from the upper part of the tank and the latter from the bottom of the tank which usually has a conical bottom to facilitate sludge removal.

Supernatant liquor is withdrawn from the digestion tanks when raw sludge is added; intermittent addition in rotation to several tanks is generally practice in preference to continuous addition. Supernatant liquor should be fairly free of suspended matter. It is high in B.O.D. and has a high chlorine demand, both of which vary with the solids carried. It is usually returned to the incoming raw sewage; it may be treated by aeration, elutriation, or settling before return.

Digested sludge is drawn at intervals from the bottom of the tank and transferred to the next step in the process, dewatering. Digestion reduces the amount of sludge solids by 35 to 50 per cent and the volume of sludge by about one-half, while the concentration of solids is practically doubled. Since digestion takes place in two stages (gasification and liquefaction, and dewatering of colloids), it has been found advantageous to separate the two stages into two tanks; i.e., two-stage digestion, with 65 to 75 per cent of the total digestion capacity in the first stage. Usually only the first stage is heated and provided with gas collection. The over-all capacity and cost of construction and operation can be reduced.

Operation Problems

Among the problems of sludge digestion tank operations are (1) mixing raw sludge with undergoing active digestion (i.e., seeding), (2) heating, (3) scum formation, (4) ineffective separation of sludge and supernatant liquor, (5) foaming and (6) fine sand.

The design of modern tanks has been developed to minimize all of these problems. For example, digestion tanks may have fixed or floating covers; each has certain advantages. Floating covers submerge the scum and keep it from drying out and utilize recirculation of supernatant liquor or digested sludge to "knock down" the scum, and maintain good seeding.

Fixed cover digesters may employ mixers in the covers or down draft mixing tubes in the center of the tanks to provide mixing of seed and raw sludge and to minimize scum formation. Heating is accomplished by coils around the tanks or by external heat exchangers which provide heating and thorough mixing of seed and raw sludge and reduce scum.

The latest method for controlling scum formation is the recycling of gas from the digester into the area of the scum layer (the PFT-Pearth System) or into the sludge compartment (The Chicago Pump Co. Catalytic Reduction Process).

Where poor supernatant liquor exists because of lack of separation of sludge and liquor, the cause is usually due to high loadings of solids per unit capacity and to high gas production rates per sq ft of surface area in the tank. Special devices, essentially screens, are available to aid in assuring that the best supernatant liquor will be selected for withdrawal.

Foaming is a condition which results when digestion proceeds at rates above normal for the particular tank. This condition occurs when tanks are overloaded, or when tanks are overfed at low temperatures and then warmed up to normal operating temperatures. Overloading often will produce an excess of volatile acids which depress the pH to a point where digestion practically ceases. This is sometimes termed a "stuck" digester. Remedies consist of discontinuing feeding or

Superior DUAL-FUEL ENGINES CUT OPERATING COSTS

in New York sewage treatment plant

Six Model 80 Superior Dual-Fuel Engines, operating 92% of the time on sewage gas, run six 1125 KVA generators to provide the sole power source for all plant equipment at The Department of Public Works, Owl's Head Sewage Treatment Plant, New York City, having a capacity of 160 million gallons per day.

After a total of 78,000 hours running time, the New York maintenance crew completed the first overhaul of the six Superior engines. Practically no major part replacements were necessary! There was no noticeable wear on the cylinder liners, bearings or other vital parts! Since the engines were torn down, piston rings were replaced; but the old rings were still good enough to save for spares! Records show very low lube oil consumption and pilot fuel costs figure out to only 9 tenths of a mill per KWH. This Superior performance is cutting operating costs to a bare minimum at New York's Owl's Head Plant!

Similarly outstanding performance records are being established throughout the U.S.A., and most other parts of the world where Superior and Atlas Diesels are used for all kinds of power needs. For complete details on how Superior and Atlas power can cut operating costs for you, contact the nearest sales and service office listed below.

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THE WHITE MOTOR COMPANY • *Plant and General Offices: Springfield, Ohio*

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adding lime to neutralize the acids.

Fine sand (60-100 mesh) will not settle out in grit chambers but will settle in primary sedimentation tanks. This settled sand will be removed with the sludge in the clarifiers and will be pumped to the digesters. Since there are no scraper mechanisms, the fine sand will collect on the sides of the cones in digestion tanks and gradually build up a hard layer which will not be removed with digested sludge, but will reduce the tank capacity available for sludge digestion. Dewatering and cleaning the tank is necessary.

Control

In addition to relatively close control of temperature, near 95° F, tests should be made to ascertain the volatile acid and alkalinity content and the pH of the liquor.

Sludge additions should be made at relatively constant rates to assure constant and uniform food supply for the active bacteria. The solids content of the sludge should be as high as possible to avoid unnecessary heating of useless cold water

Digested sludge withdrawals from the tanks should be at relatively low rates in order to avoid withdrawing good active seed material. Where two stage digestion is practiced transfer from the first to second stages should be at low rates and never in quantities that deplete the seed sludge in the first stage.

Observations of the character of the digested sludge help the operator to control the withdrawals. It is also possible to analyze the sludge for volatile matter content to determine whether or not digestion is complete. No definite value can be assigned to the relation between volatile acid content and the state of satisfactory digestion but 2000 ppm is probably the desired upper limit.

It has been found that there is a relatively stright line relationship between the volatile matter content of the raw sludge and the per cent reduction necessary to produce a well digested sludge. For example, in a raw sludge containing 80 per cent volatile matter, each 100 lb of dry solids contains 80 lb of volatile material and 20 lb of ash. If that sludge is decomposed to a well digested condition the 20 lb of ash will have associated with it 16 lb of volatile matter (i.e., it will contain 43 per cent volatile matter). Therefore the original volatile matter of 80 lb has been reduced to 16 lb or a reduction of 83 per cent.

Likewise when a raw sludge of 55 per cent volatile matter is digested to a satisfactory condition, it will contain approximately 45 per cent volatile matter or a reduction of approximately 33 per cent. A straight line can be drawn between these two points to predict the per cent reduction for other raw sludge of different composition.

Garbage Digestion

Ground garbage may be introduced into the sewer system from home garbage grinders, or it may be ground at a central location and introduced into the sewer system, or it may be ground at the sewage treatment plant and introduced directly into the sludge digester. The latter system produces the fewest operating problems at a sewage plant.

The amount of garbage contributed to the system is approximately 0.5 lb per person per day. Of this approximately 75 per cent is moisture. The dry solids, contain from 85 to 90 per cent volatile matter. When ground garbage is introduced into the sewers, there is an increase in grit removed in the grit chambers, and an increase in suspended solids and B.O.D. load on the plant.

Garbage solids digest well, but careful control of loadings is necessary to prevent volatile acid development. Combinations of garbage and sewage solids on a 1 to 1 ratio of volatile matter content can be easily handled. Gas production is increased as is the methane content of the gas.

Gas Production and Composition

The quantity and composition of the gas and the dissolved products can be mathematically predicted if one knows the composition of the organic matter undergoing digestion (i.e., the carbon, hydrogen, oxygen, nitrogen, phosphorus, sulfur content of the organic matter). Under normal conditions of operation the gas produced from sewage sludge contains 50 to 55 per cent CO_2 and 60 to 65 per cent CH_4, less than 1 per cent hydrogen and hydrogen sulfide combined and 2 to 5 per cent nitrogen (from dissolved air in raw sludge); it has a heat value of approximately 600 to 650 Btu. per cu ft. About 1 cu ft of gas is produced per capita per day.

Under optimum conditions of temperature (85 to 90 deg. F.) and pH (6.8 to 7.4), about 50 per cent of the gas produced will be given off in 24 hours, with the other 50 per cent evolved over the next 20 to 50 days (about 90 per cent in one week). Rate of gas production per day varies directly with temperature of the digesting mass.

Gas Utilization

Provision is generally made for collecting and utilizing the gases produce. Limited amounts of gas may be stored under either floating or fixed covers. Larger quantities may be stored in spherical pressure holders or gasometers.

Gas produced by slude digestion are quite usable for several purposes, principally for heating plant buildings, for heating sludge digestion tanks, for burning dried sludge, for internal combustion engines to produce power and for laboratory uses.

When used for heating buildings the gases are burned in a furnace equipped with dual burners to permit the use of oil when gas production is low. Dual burners are also required in furnaces for drying sludge and in external heat exchangers for heating sludge digestion tanks. Heat exchangers can operate directly from combustion of fuel or can be adapted for use where gas is utilized as a source of power for gas engine operation. In this case, engine jacket heat can be dissipated by circulation through the water bath of the heater.

One of the most profitable uses of sludge digester gas is to operate internal combustion engines for power production or to operate blowers in activated sludge plants, or to operate pumps. For normal gas production of approximately 1 cu ft per capita per day (650 Btu per cu ft), it is calculated that 2.5 hp per hr can be produced for each 1000 persons in gas engines designed for sludge gas. In dual fuel engines operating on the diesel cycle, gas consumption is approximately 11 cu ft (with 5 percent of total Btu input as pilot oil for each bhp, compared with 15 to 15.5 cu ft of sludge gas per bhp per hr in the four cycle otto engine. Thus with dual fuel engines, ⅔ bhp per hr can be produced from the daily gas production of a population of approximately 650 persons. If garbage is digested this value is approximately doubled.

If the gas contains much hydrogen sulfide, it must be scrubbed or the corrosive action will be objectionable. The H_2S content should not exceed 0.07 per cent by volume or 50 grains per 100 cu ft. Hydrogen sulfide is removed in scrubber containing finely divided iron oxide in wood shavings.

Gas engines for use on sludge gas may be obtained in sizes from 15 to 1800 hp. They may be connected to generators, air blowers, or sewage pumps through gearing. Hundreds of these engines are now in use in sewage plants. The dollar savings from the use of gas engines is appreciable. In one city of 30,000 population where diffused air aeration is used in the activated sludge process, the yearly "earnings" of gas engines was nearly $8000.

Sludge Digesters

Mechanical Equipment is important part of separate sludge digestion systems

by FRANK L. FLOOD

Partner, Metcalf & Eddy, Cons. Engrs., Boston, Mass.

CONSIDERABLE mechanical equipment is usually involved in modern separate sludge digestion systems. Among the more important items requiring consideration are, floating covers, gasometer-type covers, fixed steel covers, heating systems, sludge removal, recirculation systems, gas collection, supernatant withdrawal and scum control.

Floating Covers

John R. Downs, Superintendent of the Joint Meeting Sewage Treatment Plant at Plainfield, N. J., is credited with the design of the first floating cover for a separate sludge digestion tank in the United States. The simple wooden cover designed by him has been developed by the Pacific Flush Tank Co. into a modern mechanism built of steel with guides, controls, supernatant selectors, pressure and vacuum relief valves, gas domes, manholes, sampling hatches, level indicators and other appurtenances. The original floating cover patents have expired and other companies now compete for the floating cover business. This relatively new competitive condition places a responsibility on the engineer to draw up plans and specifications which will assure truly competitive bidding and that his client will receive equipment which will meet the requirements for service and long life.

The engineer is also responsible for weighing the costs and comparative advantages and disadvantages of the floating covers with gasometer and fixed covers of various types and forms.

There has been some experience with tilting of covers with resultant jamming and some damage to the equipment. Guides and extended rollers have been used in some instances for the purpose of controlling tilting.

Under certain conditions floating covers have been known to freeze in a fixed position for several weeks at a time. Heat has been applied to the annular ring between the cover and the tank walls to correct this condition.

The natural weight of the floating cover may not provide the desired gas pressure. In some instances weight has been added to the cover to increase the gas pressure.

The floating covers ride on the liquid surface or scum. Provision should be made to prevent the rapid loss of heat through the cover. This can normally be accomplished by covering the roof over the ceiling plate with corkboard, foam glass or other insulating material. The insulating material should be protected by roofing. In some instances heat has been applied to the air space between the ceiling plate and roof in order to heat the top of the digestion tank[1].

Gasometer Type Covers

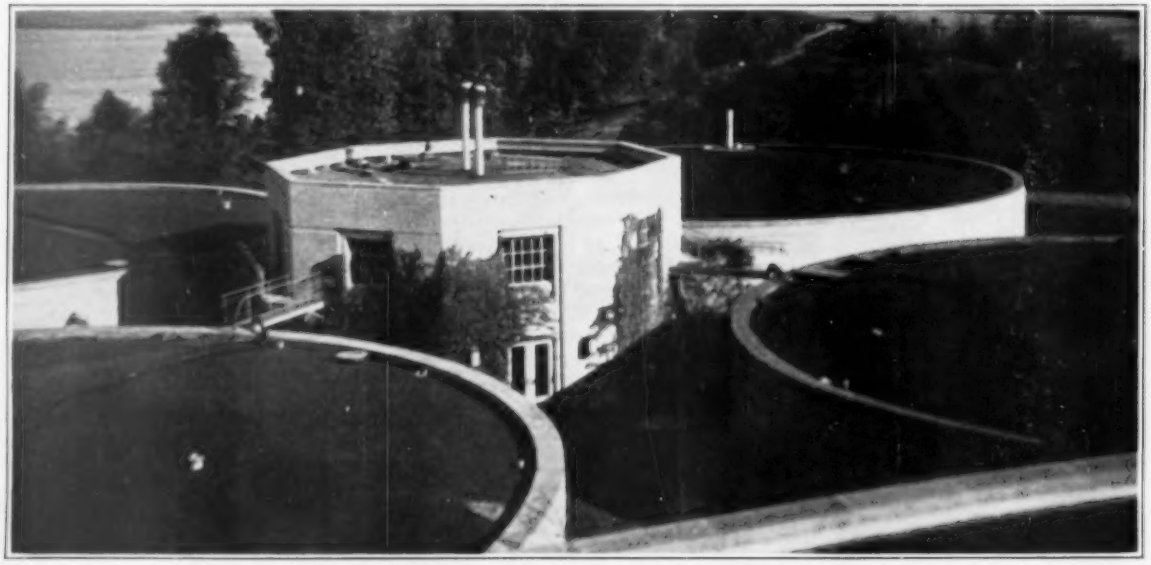
The gasometer type of cover has been extensively used by the Dorr Co. in the secondary tank of its so-called Multi-digest system. It is also quite commonly used where engineers desire a relatively small volume of gas storage and find it convenient to provide this at a digestion tank, or a sludge storage tank, rather than in a separate holder. The depth of gas storage under the gasometer cover is usually on the order of 2 to 6 ft. or more. The Dorr Co. has used a center column and Pacific Flush Tank Co. has used a spiral guide, to prevent tilting of the gasometer cover.

Fixed Steel Cover

The Dorr Co. has commonly used a fixed-steel cover on the roofs of primary digestion tanks in its Multi-digest system. Competitive bids between fixed steel domes and fixed concrete roofs for the large digestion tanks at the Los Angeles Hyperion Plant in 1948, favored concrete dome roofs.

Heating Systems

For about 20 years prior to 1947,

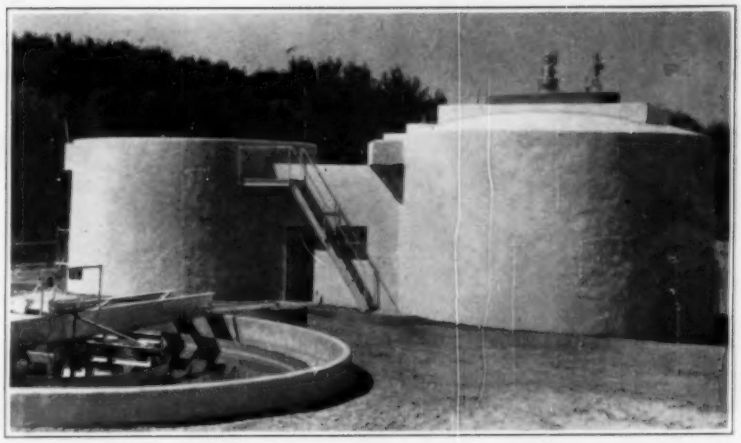


Separate sludge digesters with P.F.T. Floating Covers—Buffalo, N. Y.
Sludge control house center, has P.F.T. heat exchangers, control devices, and pumps

the majority of digestion tanks were heated by means of hot water circulated in coils within the tanks. These installations if designed with ample area and operated at relatively low temperature of hot water, if constructed of suitable materials and joints, if adequately supported and if not seriously affected by electrolytic action, have given very satisfactory service. There are enough "ifs" in the design, construction, and operation of those heating coils so that failures have been recorded.

Recently the tendency has been away from the use of hot water coils inside the tanks towards enclosed heat exchangers outside the tanks. This has been promoted in part by the sales efforts of the manufacturers, particularly at first by the Pacific Flush Tank Co. and more recently by Walker Process Equipment Co., the Dorr Co., and others. The separate heat exchangers are usually designed to heat the raw sludge being admitted to the tank or liquor circulated from the tank. In the latter case, the heated recirculated liquor may be added to the raw sludge for rapid conditioning.

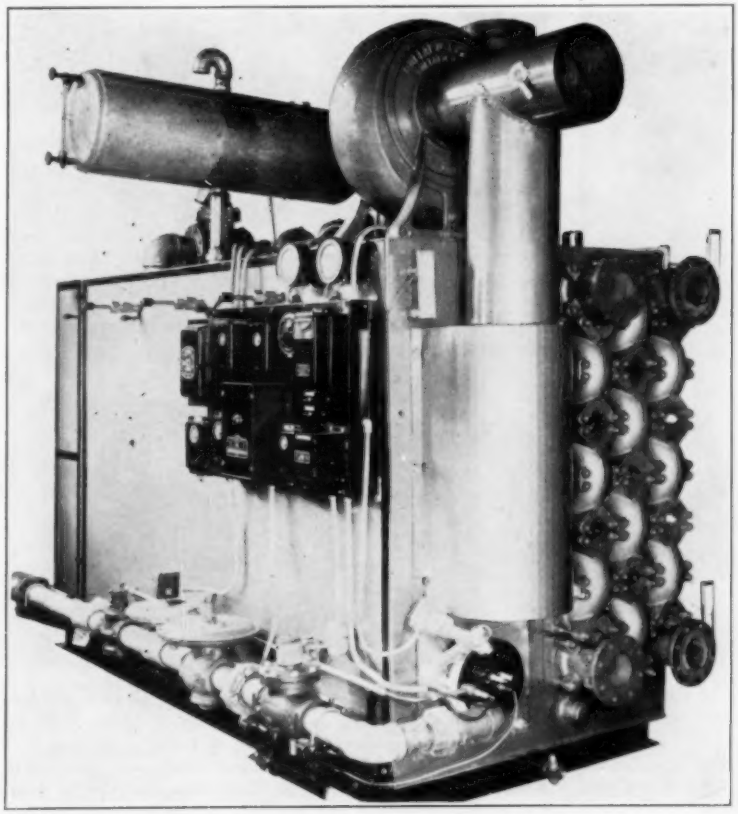
Direct contact combustion heaters have been installed in the digestion tanks at Baltimore[2] and at Philadelphia[3] and the control of temperature in digestion tanks with live steam has been described by Rawn[4].



Dorr Co. Multidigestion System at Carmel, Calif.

The digestion tanks at the Los Angeles Hyperion plant are heated by means of steam admitted into the flow tube below the impellers of Dorr mixers. The steam is reclaimed from the vapor phase system at the dual fuel gas diesel engines. Where direct steam heating is used, the water should be treated as required to prevent operating difficulties at the steam boilers.

Infilco, Inc. has developed a so-called "Verti-Flo" impeller for installation in the scum zone of digestion tanks. Heating coils are installed at the mixer in a vertical bank which can be withdrawn through a manhole in the roof.



P.F.T. Hot Water Type Heater and Heat Exchanger—Stockton, Calif.

Scum Control

Possibly the greatest single difficulty experienced with the operation of sludge digestion tanks has been in accumulation of masses of relatively inert scum which renders ineffective a substantial proportion of the tank capacity, clog supernatant and overflow pipes, and create numerous operating problems. It appears that if the scum is kept well mixed with warm tank liquors, the scum-forming materials will continue to digest and for the most part settle to the bottom with the sludge. If well lubricated by tank liquors, excess accumulations of floating materials can be withdrawn through piping connections in the upper portions of the tank.

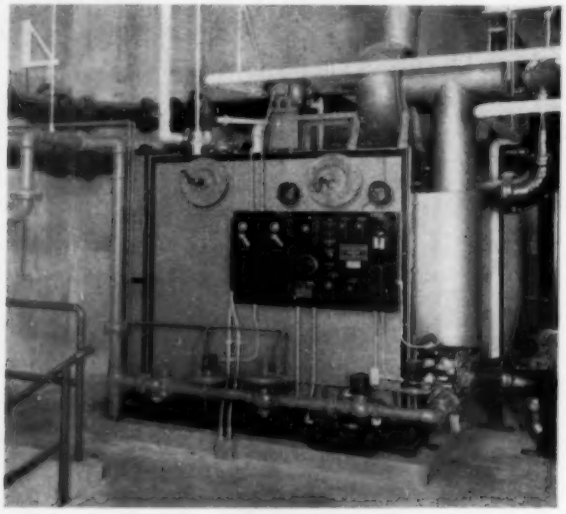
Several schemes have been developed designed to meet the scum problem. A few will be briefly described. In tanks equipped with floating covers, the Pacific Flush Tank Co. recommends the installation of a circulation system designed to produce a flow and mixing action at the center of the tank in the gas dome. In theory, scum accumulating unde rthe floating cover and outside the limits of the gas dome will flow into the center and receive treatment.

The Dorr Co. recommends the installation of propeller mixers installed in the scum zone below the roofs of fixed-roof tanks. These are designed to mix the scum with the underlying

P.F.T. equipment and methods for modern waste treatment

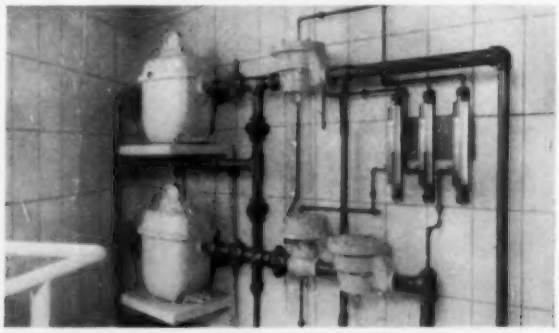
Cities and industries of all sizes have used PFT equipment and processes for effective waste treatment since 1893. Whether extending capacities, converting to newer methods or installing new systems, PFT equipment is economically adaptable to existing structures. Suitable to all current waste treatment systems, PFT equipment ranges from the smallest siphon to the largest municipal installations. PFT stands squarely behind its products and provides expert *field service* as long as its equipment remains in use.

Floating Covers —An integral part of "controlled" digestion, PFT Floating Covers provide positive scum submergence and safe utilization of gas. Operations are simplified because no fixed levels need be maintained. Covers simply rise or lower with additions and withdrawals. Available in different shapes and sizes for various tank requirements. Complete data on properly sized covers furnished on request. Submit the total digester volume required and number of digesters contemplated.



Digester Heaters and Heat Exchangers—External heaters for digestion tanks allow complete accessibility in a compact unit of high thermal efficiency. Raw sludge or a mixture of raw and recirculated digester contents is heated as it passes through the unit. With external heating, the problems of heating coils within the tanks (caking, corrosion) are avoided. Cleaning and maintenance are simplified. Detailed drawings and estimated digester heating loads furnished on request. Submit the number of digesters, tank capacities and quantity of raw sludge.

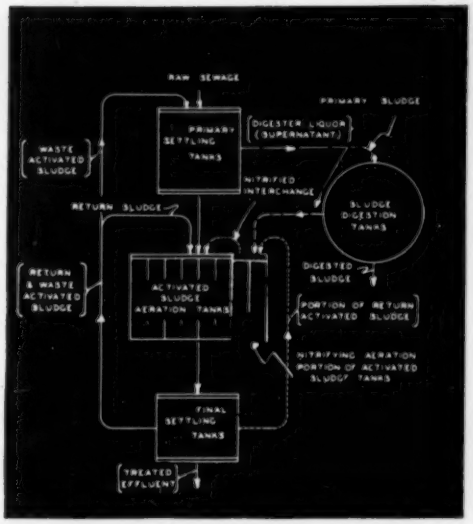
Prefabricated Metal Roofing —This type of roofing provides four distinct advantages over conventional wood types: (1) longer life, (2) more efficient insulation, (3) fewer maintenance problems, (4) easier assembly and installation. Each prefabricated section is designed for close fitting in the field with a 3″ lap of top metal covering at all joints.

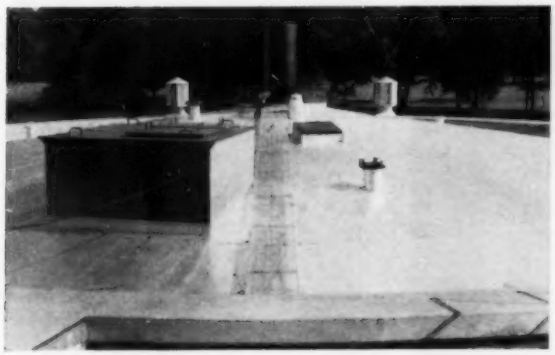


Gas Safety Equipment —A number of devices, each designed to perform its function in a gas utilization system with the greatest possible protection against explosive or burning mixtures of sludge gas and air: flame traps, pressure reliefs, pressure reliefs combined with flame traps, flame cells, waste gas burners, drip taps, accumulators and manometers.

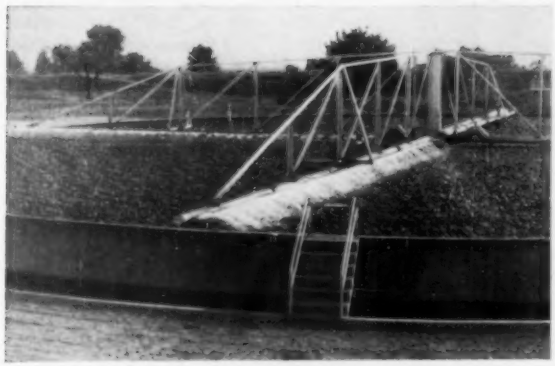
Kraus Interchange Process—A process of aerating waste activated sludge, utilizing the digester supernatant liquor to produce highly nitrified solids that: (1) During *normal* loads, produce sludge that settles more readily to provide greater purification. (2) During *peak* loads, provide a reserve of highly nitrified active solids which balance the increased load of organic matter. A truly "controlled" activated sludge process.

Kraus Distributed Air Process—A new method of introducing air into aeration tanks. Combined with the Kraus Interchange Process, it provides: (1) Greater Stability of activated sludge treatment, (2) More efficient treatment of shock loads, (3) More efficient use of aeration tank capacity, (4) Lowered power requirements for air.

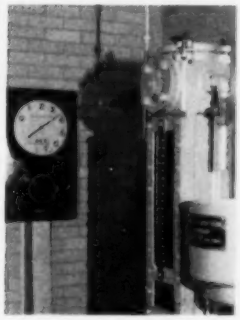




Pearth Gas Recirculation System—An effective method of increasing dispersion and digestion of scum, allowing full effective use of total digester volume at all times. Designed as an integral part of the PFT Floating Cover, the Pearth system breaks up the scum and releases entrained gas by recirculating digester gas and discharging below the scum level. Complete data on the Pearth Gas system on request. Submit digester volume, diameter and number of digestion tanks.



Rotary Distributors—Soundly engineered and ruggedly constructed, PFT Distributors provide even distribution of settled sewage over the surface of a trickling filter. Specially designed spreader jets reduce clogging and are easily cleaned. For hydraulic design of equipment, submit diameter of filter bed, total head available, maximum and minimum flows desired.



Digester Accessories—The PFT Supernatant Selector, Gauge, Sight Glass and Sampler units provide automatic withdrawal of the best digester liquor at a slow, continuous rate. The PFT Cover Position Indicator reflects the slightest Floating Cover movement on a large dial in the Control Room, showing digester liquid level at a glance.

Illustrated Bulletins—Detailed information on PFT equipment is available in a series of technical bulletins, fully illustrated with photographs and diagrams. Please specify the equipment in which you are interested. Address all inquiries to Dept. RD, Pacific Flush Tank Company.

Technical Studies Available—The following studies are available without charge: "*A Rugged Activated Sludge Process*", by L. S. Kraus; "*Scum Control in Sludge Digestion*", by R. E. Fuhrman; "*What You Should Know About Sludge Digestion*", by H. E. Schlenz; "*Controlled Humus Production*", by L. L. Langford.

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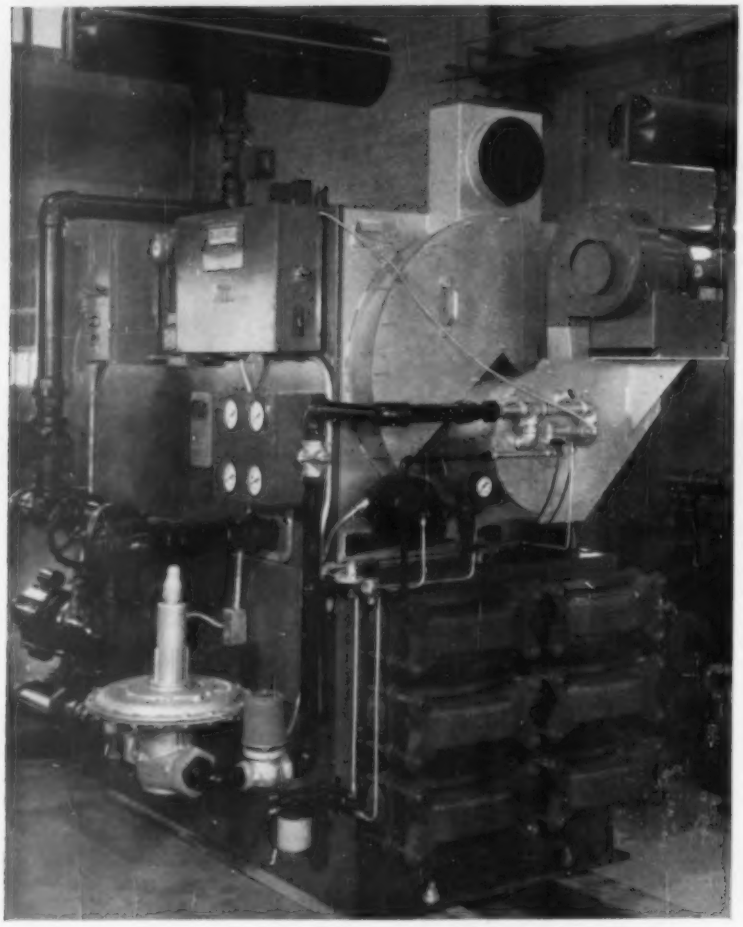

Walker Process Equip. Co. Heat Exchanger

tank liquor. Favorable results have been reported with this equipment at Stamford, Conn. Units of this type have been installed in the digestion tanks at the Hyperion Plant in Los Angeles. Where particular types of industrial wastes conducive to the formation of very heavy scum masses are to be encountered, this company has recommended mechanical mixers with slowly revolving stirring arms passing between fixed teeth suspended from the roof. Similar equipment is supplied by Hardinge Co., Yeomans Bros. Co., and Infilco, Inc.

For circular fixed roof tanks, the author[5] has recommended the circulation of liquor at relatively high rates, the liquor being drawn from beneath the scum zone and discharged just above the normal liquid or scum level. Four discharge nozzles are provided located at about quarter points in plan and inclined at about 45°, directed so as to cause a circulatory motion in the scum and to bring scum not directly under the nozzles into the active turbulent mixing areas. An installation of this type on a primary digestion tank, 50 ft. in diameter, at Bristol, Conn., has proven very effective in quickly eliminating a mass of heavy scum which formed during the early weeks of operation before the circulating liquor was discharged through the scum nozzles above the liquor level. After this heavy scum was eliminated, it has been found practical to restrict scum accumulation to a relatively thin soft layer by operating the recirculation system a few hours each day.

For square or rectangular tanks, the Link-Belt Co. makes a scum breaker which consists of a number of paddles attached to a pair of endless chains moving through the scum at a speed of about 1 fpm. The return flight is through the mid depth of the tank.

Sludge Removal Mechanisms

In the earlier designs, digestion tanks were equipped with sludge removal mechanisms similar to those provided for circular and rectangular sedimentation tanks. The operation and maintenance of this equipment proved to be difficult and expensive. Recently circular tanks have been provided with inverted conical bottoms to promote the withdrawal of sludge without the aid of mechanical equipment. Relatively few rectangular digestion tanks have been built or proposed during the recent years.

Supernatant Withdrawal

Normally as raw sludge digests there is a separation of relatively dilute liquor from the concentrated sludge or scum. This dilute liquor usually collects over the bottom sludge and under the scum layer. In the majority of plants multiple pipe connections are made to the tanks in the zone where dilute liquor is most apt to collect and provision is made for supernatant withdrawal by selection after sampling to determine where the clearest liquor may be obtained.

The new tanks at the Hyperion plant in Los Angeles are equipped with a swivelled supernatant withdrawal pipe operated by means of a cable and winch rigging. The cable passes through the tank roof by means of a Varec fitting designed for a 12-in. water seal.

The Pacific Flush Tank Co. advocates the use of its "Supernatant Selector." This consists of a slotted tubular device mounted vertically at the central portion of the digester and extending throughout the portion of the depth from which supernatant in normally withdrawn. The tube is made with slots that are intended to be sufficiently narrow to hold back liquid containing large amounts of suspended solids and to pass the clearer liquid for withdrawal from the tank. Provision is recommended for back-flushing as needed to clear the slots.

Gas Domes

In some early designs of digestion tanks, gas was withdrawn from a low, small dome, not much more than a manhole cover, in the roof not far above the sludge level. Experience soon indicated the need for larger and taller domes as under high rates of gas production there was at times sufficient disturbance of the liquid surface under the dome to carry moisture and particles of sludge and scum into the gas system. With domed roofs, the clearance between the liquid level and dome at the center of the tank is usually sufficient to minimize the requirements for a separate gas dome. For flat concrete roofs and floating covers, more elaborate gas domes should be provided.

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through exclusively highest solids loading for sludge digestion

RESULTING IN:

1. Smaller tanks
2. 1/3 to 1/7 of former digester volume for biological requirements of sludge digestion* (Contrasted to actual requirements of former methods of digestion).
3. Non-formation of dense floating solids, termed "scum", eliminating former pro-ration of digester volumes for holding "scum".
4. Consistently highest degree of volatile solids reduction and gas production — through fundamental application of a simple gas diffusion mechanism — with lowest tank volume and simplified piping, without increase in operation supervision requirements.

**Exclusive of sludge storage volume that may be required by subsequent disposal methods.*

Reports Available

Reports describing the PROCESS in detail are available on request. Write to Department F.

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Subsidiary of Food Machinery and Chemical Corporation
SEWAGE EQUIPMENT DIVISION
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Eight 110-ft. diameter Chicago-Wiggins Lodek Covers at the City of Philadelphia Southwest Disposal Plant.

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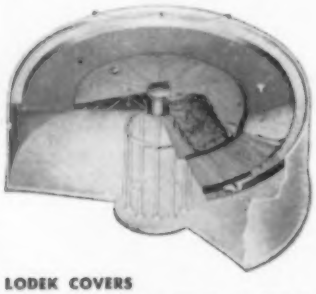
PONTOON COVERS
Always float on liquid — never on gas



LODEK COVERS
Lowest first cost for 75 ft. to 150 ft. diameters.

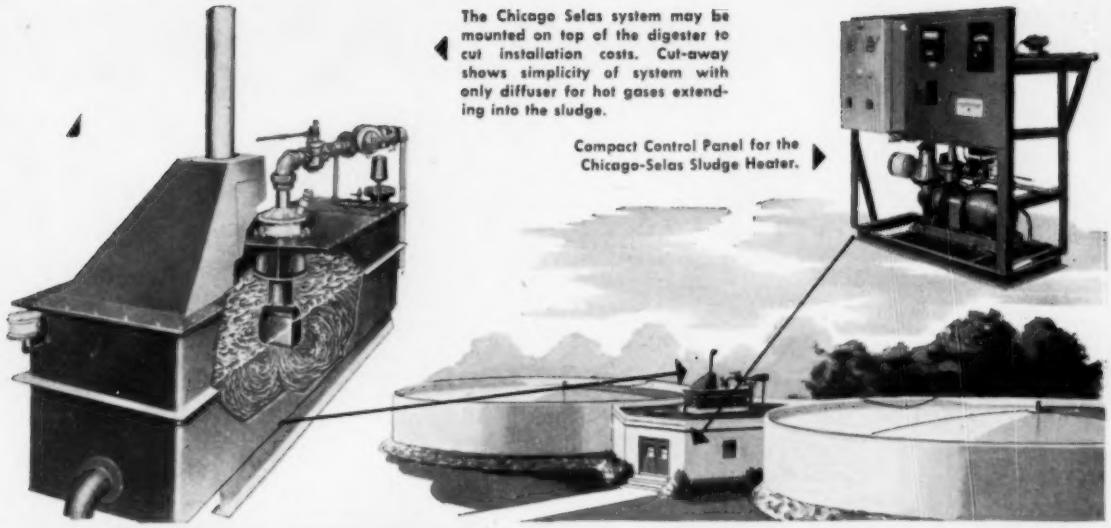
WET GAS HOLDERS
Self balancing with a positive seal. Economical in first cost and in maintenance.

Chicago-Wiggins DIGESTER COVERS and HOLDERS

Improved digestion gained through non-tipping cover construction

Maximum gas pressure and positive scum submergence achieved

MORE THAN 50 INSTALLATIONS IN MAJOR CITIES



The Chicago Selas system may be mounted on top of the digester to cut installation costs. Cut-away shows simplicity of system with only diffuser for hot gases extending into the sludge.

Compact Control Panel for the Chicago-Selas Sludge Heater.

SEWAGE DIGESTION EQUIPMENT

Chicago-Selas HEAT TRANSFER SYSTEMS

MAXIMUM EFFICIENCY—One pass through the small heat transfer tank boosts sludge temperature 10 to 20 degrees F. Approximately 90% of heat available in the digester gas is transferred directly to the sludge.

LOW COST INSTALLATION—Heater and transfer tank may be located at digester, requiring minimum piping and valves.

NO HIGH COST OIL STAND-BY EQUIPMENT—Operates efficiently on nationally available manufactured gas if necessary. A single control valve is the only stand-by equipment required. Low gas consumption makes Chicago-Selas system ideal for medium sized plants with limited gas production.

UNIFORM HEATING—Agitating action of heated gases expelled into transfer tank assures complete heating of all sludge.

MINIMUM MAINTENANCE—Heat is distributed without mechanical equipment in the tank. No sludge tubes to cake—no cleaning.

PRECISE TEMPERATURE CONTROL—All gas control and safety equipment is approved by Associate Factory Mutual Fire Insurance Companies.

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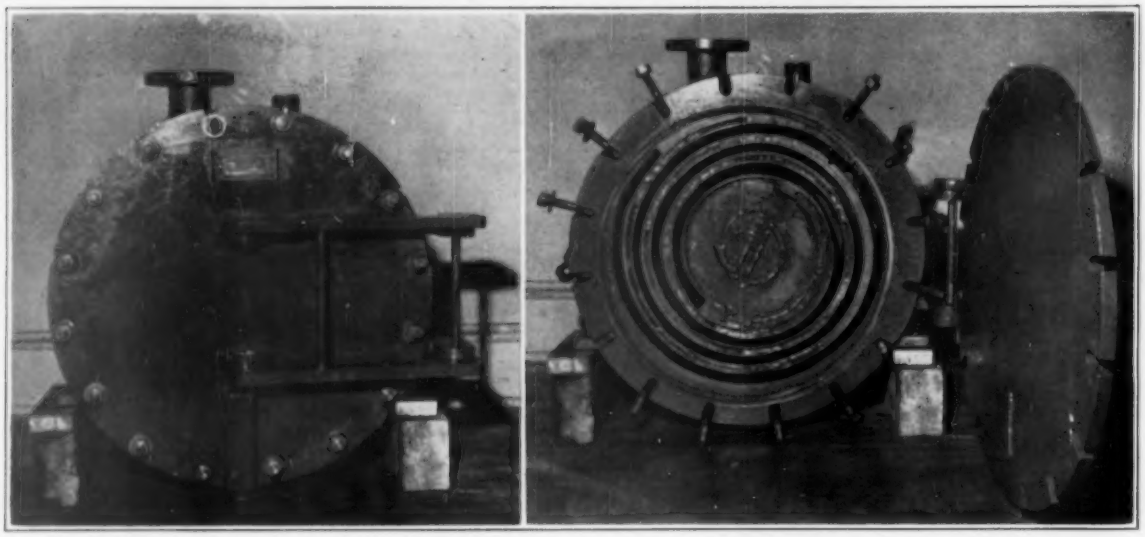
Flush Kleen ®, Scru-Feller ®, Plunger, Horizontal and Vertical Non-Clogs Water Seal Pumping Units, Samplers . . . Swing Diffusers, Stationary Diffusers, Mechanical Aerators, Combination Aerator-Clarifiers, Barminutor ®, Comminutors.



(With front door closed) **Dorr Co. Counter Current Flow Type Spiral Heat Exchanger** (With front door open)

Pressure and Vacuum Relief

Sludge digestion tanks, ragardless of the type of roof, require provision for pressure and vacuum relief. Undue pressure within a tank may be created by sludge inlet pumps operating at a time when all outlets to the tank are closed or clogged. A vacuum may be created by the withdrawal of sludge at a greater rate than sludge is being admitted or sludge is being introduced.

Early designs of pressure and vacuum relief devices which relied on a "leg" of oil or water proved somewhat troublesome because of evaporation, freezing, "blowouts" or other difficulties.

Vapor Recovery Corp., Pacific Flush Tank Co. and others have developed valves which permit gas to escape from the tank if the pressure rises above a predetermined level or permits air to enter the tank if there is a tendency for vacuum to form. These valves are equipped with flame arresters to prevent a flame from flashing back into the tank when the vacuum release feature is operating.

Careful attention must be given to the design and operation of these valves. In one type of valve, some trouble has been experienced due to freezing of condensation in such a manner as to render the valve inoperative during severely cold weather. In another type of valve, the protection afforded depends upon the replacement of oil which may evaporate or be accidentally displaced.

Normally the floating cover is not subject to vacuum. However, in the event sludge is withdrawn while the cover is resting on the landing ledge, a sufficient vacuum can be created, unless a vacuum relief valve is provided, to cause serious structural damage to the cover.

General Comment

Particular attention should be given to the protection of structural steel members, cables, and other metal parts immersed in sludge digestion tanks from the corrosive effects of sewage sludge and possibly also from galvanic or electrolytic action. The difficulties encountered in the latter respect in a sludge digestion tank at the Terminal Island plant in Los Angeles have been described by Parkes[6].

Oil and grease lubricated bearings should not be used inside of digestion tanks. It is preferable to support rotating equipment from the structural roof using thrust bearings.

Piping should be designed of generous size. Maximum rates of gas production may be several times the average rate and should be provided for. Undersized sludge inlet and withdrawal piping has led to serious difficulties in a number of instances.

For the most part, the equipment installed within digestion tanks prior to World War II has not proven very satisfactory. The work of cleaning out a digestion tank and the making of repairs on mechanical equipment installed therein is laborious and distasteful to the operators. In many small plants with only one or two tanks, the withdrawal of one tank from operation to make repairs may necessitate by-passing a portion, if not all the sewage flow, during the repair period.

It is hoped that the newer developments will prove longer lasting and more effective than some of the earlier.

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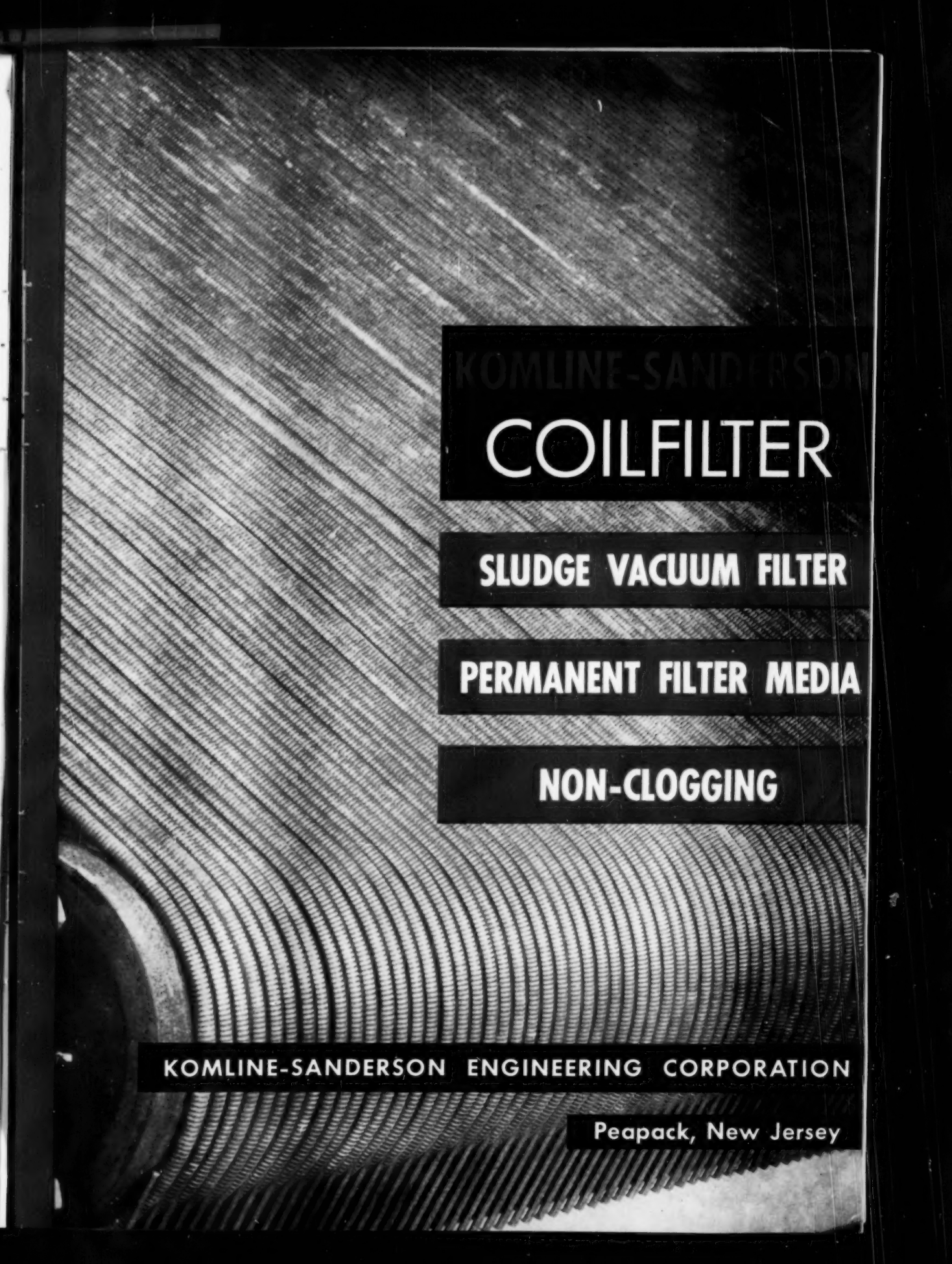

KOMLINE-SANDERSON
COILFILTER
SLUDGE VACUUM FILTER
PERMANENT FILTER MEDIA
NON-CLOGGING
KOMLINE-SANDERSON ENGINEERING CORPORATION
Peapack, New Jersey

KOMLINE-SANDERSON COILFILTER

The filter with the *proved* permanent type filter media . . . .

COIL SPRING FILTER

Permanent type filtering media, consisting of a series of stainless steel helically coiled springs, made endless by joining the two ends of each spring with a threaded plug—mechanically rugged, corrosion resistant—has a useful life of many years.

NON-CLOGGING

Original, proved Coilfilter design provides *automatic* and *thorough* cleaning of filter media after discharge of filter cake and before entering the vat, without removal from the drum.

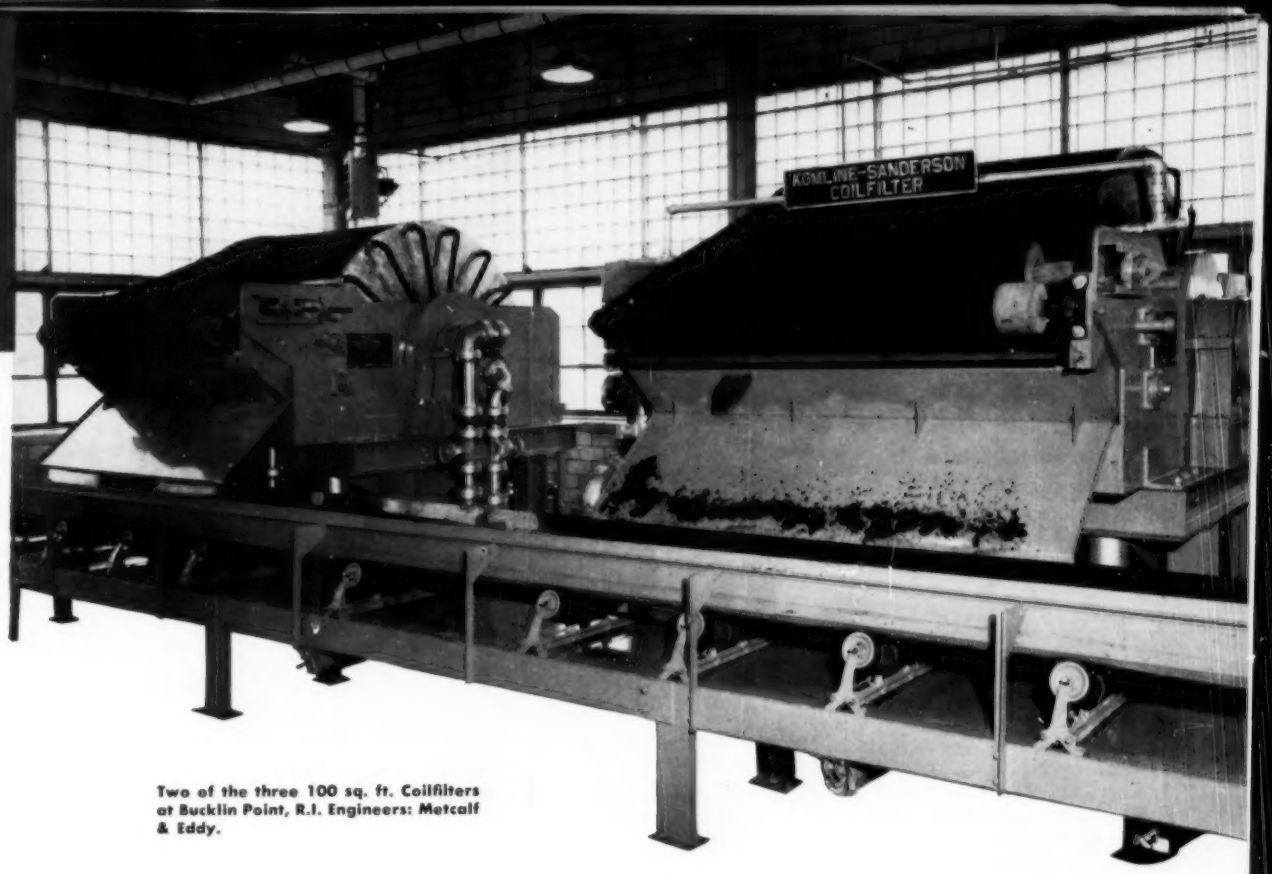
CONSTANT OUTPUT

Since the filter media is completely cleaned after each dewatering cycle, there is no progressive clogging. Consequently uniform production of filter cake is maintained, without the necessity of costly controls.

LOW OPERATING COST

Rugged, non-corrosive alloy steel construction, external easy-to-reach piping, simple operation, lower chemical requirements for sludge which must be chemically conditioned. Low labor costs—negligible maintenance—as indicated by performance record of machines in operation since 1949.

Two 200 sq. ft. Coilfilters at Darby, Penna. Engineers: Damon & Foster.



Two of the three 100 sq. ft. Coilfilters at Bucklin Point, R.I. Engineers: Metcalf & Eddy.

COILFILTER PERFORMANCE

The Coilfilter is the most successful of modern sludge vacuum filters. Its outstanding performance is being demonstrated in day-by-day plant operation, dewatering many different types of sludge.

Filter cake production is greater than from any other type of sludge dewatering equipment. Sudden changes of sludge-characteristics do not upset Coilfilter operation. Chemical conditioning is far less critical than with other types of vacuum filters. Output is uniform because the filter will not clog or blind. Standby filters are not necessary, since the equipment does not have to be taken out of operation for cover changing or replacement.

FRESH SLUDGE DEWATERING

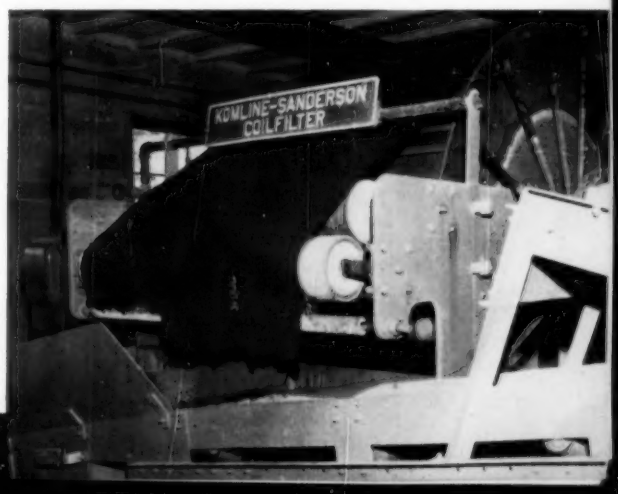
Because the Coilfilter dewaters fresh sludge directly, at high filter rates and with low chemical conditioning requirements, basic plant design and subsequent operation can be simplified, resulting in economies both in initial costs and operating expenses. The application of lime and ferric salt effectively deodorizes and stabilizes the fresh sludge and filter cake. Digesters are expensive to build, and often present operating difficulties which adversely affect the rest of the plant. Many engineers now prefer to eliminate the digestion stage, and dewater on Coilfilters the fresh sludge from either primary or complete treatment plants. The Coilfilter has made this economically feasible, since spare filters are unnecessary.

85 sq. ft. Coilfilter at Perryville, Mo. Engineers: Russell & Axon.

COILFILTER ECONOMY

The proved economy of Coilfilter installation and operation is the principal factor in the outstanding acceptance of this equipment.

1. *Low Initial Cost.* Single units in compact, one story buildings make for more attractive workable installations at minimum capital expenditure.
2. *Rugged Construction.* Has resulted in a phenomenal low record of parts replacement for the Coilfilter. Cross-section of wire used in filter media is .063" x .089". Spring diameter is .410".
3. *Low Chemical Cost.* Lower-than-optimum chemical dosages are often used in order to minimize operating costs. This is possible only with the Coilfilter, since the filter media does not blind.
4. *Low Labor Cost.* Operator's full time is not required while equipment is in operation. Easy maintenance — all piping is external.



INSTALLATION

Every Komline-Sanderson Coilfilter installation receives individual, careful attention from our Engineers, both in the office and in the field. We have developed, and are continuing to develop and improve much of the auxiliary equipment used in Coilfilter installations. In order to assume complete responsibility for the proper performance of the complete sludge dewatering installation, it is our policy to furnish all necessary equipment:

1. Coilfilter
2. Vacuum and Filtrate Equipment
3. Conditioning Tank
4. Wet Sludge Handling Equipment
5. Conditioning Chemical Feeders, Pumps and Tanks
6. Cake Handling Equipment

Our Engineering staff is ready to submit preliminary performance data involving the use of Coilfilters in your plant, upon receipt of the following information:

1. Type of treatment plant
2. Whether sludge is to be digested
3. Design data, flow and suspended solids or population equivalent
4. Number of hours of filter operation per week desired

We maintain laboratory facilities at our headquarters in Peapack, New Jersey, as an integral part of our services to our clients.

OTHER KOMLINE-SANDERSON PRODUCTS

Sludge and Slurry Pumps
Pioneer Micronic Filters
Production Weldments

WARRANTY

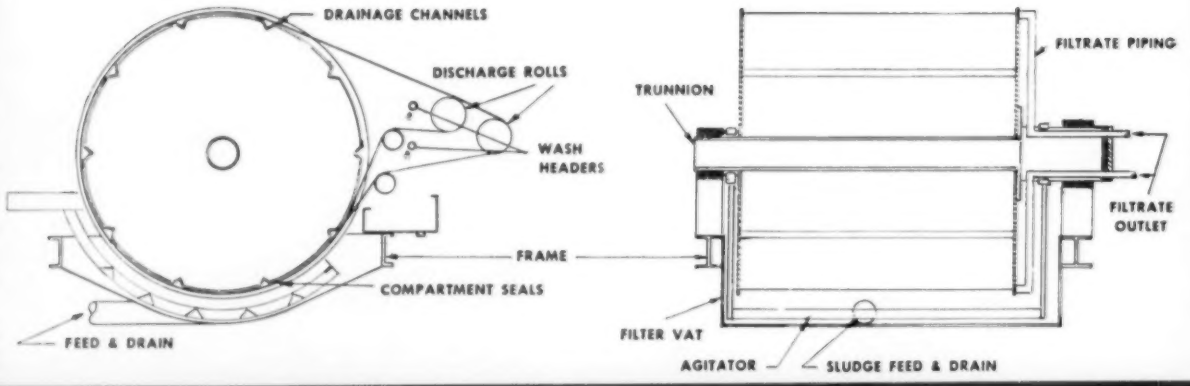
The Coilfilter is unconditionally guaranteed to work satisfactorily and filter continuously, without clogging or blinding, provided that the sludge is conditioned to the following laboratory requirements: Utilizing a No. 2A Buechner funnel and working with 100 CC sample, the sludge is to dewater to a cake of ¼ inch minimum thickness in 100 seconds. Manufacturer warrants all equipment and parts for one year, and shall maintain the filter media without charge for a period of 10 years after shipment if the filter unit is operated 40 hours per week, or its adjusted equivalent.

COILFILTER STANDARD SIZES

SIZE	AREA SQ. FT.	SIZE	AREA SQ. FT.
*6' dia. x 2'8" face	50	10' dia. x 8' face	250
**7' dia. x 4' face	85	10' dia. x 10' face	300
**8' dia. x 4' face	100	10' dia. x 12' face	350
8' dia. x 5' face	125	11'6" dia. x 10' face	350
8' dia. x 6' face	150	11'6" dia. x 12' face	430
8' dia. x 8' face	200	11'6" dia. x 14' face	500
10' dia. x 6'4" face	200	11'6" dia. x 16' face	575

*For sludges which do not require chemical conditioning
**Package Unit

Schematic layout of typical Komline-Sanderson COILFILTER



KOMLINE-SANDERSON ENGINEERING CORPORATION
Peapack, New Jersey

Sludge Elutriation

by THEODORE JAFFE

Prof. of Civil Engineering, San. Res. Lab., Univ. of Florida, Gainseville, Fla.

DISPOSAL of the sludge resulting from the treatment of sewage has always been a problem for the plant operator. In a study of Florida sewage plants[1] it was shown that sludge disposal is the concern of more than 50 per cent of the treatment plant personnel, regardless of their titles or the type of treatment provided.

Sewage sludge is disposed of in many ways. Depending upon local conditions it may be dried, burned, or removed as a liquid. No matter what the method of ultimate disposal may be, the operator's prime concern is how small a volume can be produced; the smaller the volume, the lower is the cost of disposal. And what city official would not look with favor upon lower costs, especially for sewage treatment?

To reduce the volume of sludge many devices are employed, depending upon whether the final product is to be disposed of liquid or dry. One of the devices used to produce a dry sludge is vacuum filtration. This method was extremely popular from about 1932 to 1942 and many plants still use this means of producing a relatively dry sludge for final disposal.

In most of the installations, some form of pretreatment of the sludge is required. Chemicals, such as ferric chloride, are often added to the liquid sludge, mixed, and then the "conditioned" sludge is applied to the filter. These chemicals are added to produce a filtered sludge cake containing less water (more solids) and therefore occupying a small volume.

Because the cost of the chemicals is always an additional cost of treatment—and in many cases a high cost—researchers sought ways to improve the efficiency and thus reduce the cost of this method of sludge treatment. Out of this research came sludge elutriation.

What Elutriation Is

Sludge elutriation is a process of adding water or plant effluent to the sludge, mixing thoroughly, allowing the sludge to settle and the liquid to rise. These two portions are then drawn off for further disposal.

There are many mechanical and theoretical features involved, but the basic process is the same. By adding various volumes of water (or plant effluent) two results are accomplished. First, a sludge requiring less chemicals for conditioning is obtained and, second, a more compact sludge with a higher percentage of solids is produced.

Why does the elutriated sludge require less chemicals? Suppose we assume that an operator is using ferric chloride as the conditioner. He uses a chemical to "condition" the sludge for filtration. This means that the filter will do a better job—produce a more compact sludge cake—as a result of adding the conditioner.

The operator knows that in sewage there are colloidal particles and that they are negatively charged, for the most part. He knows, further, that if the charges on these particles are neutralized, the particles will tend to flocculate and then settle out. Since they are negatively charged and since ferric chloride in solution breaks down to something called a ferric ion, each of which has three positive charges, a ferric salt should settle out a large amount of these negative colloids. When the colloids are neutralized it is found that the sludge will compact more readily and lose some of the water bound by the colloidal structure of the sludge.

Knowing this much theory, the operator tries it on his sludge. He adds ferric chloride, mixes it with the sludge and sends it to the filter. No doubt the solids in the cake will improve very little. He adds more chemical and still more, each time getting a slight improvement. The cost of these chemicals, however, soon gets out of proportion to the amount of improvement derived. It appears that something in the sludge is tying up large amounts of the conditioner.

That is exactly what takes place; a large amount of the chemical conditioner is not available for its intended job. This is a costly procedure. What is happening, and what can be done about it?

Quite a few years ago this problem was investigated by many persons. One of these was A. L. Genter, who eventually worked out a patented process of sludge elutriation. Before he obtained the patent, he did a large amount of work and was able to show[2] that this coagulant demand was due to certain substances normally found in sludges and sludge liquors, and that these substances were compounds of ammonia resulting from biological decomposition.

Further, he showed that when water of low alkalinity (titratable alkalinity, not pH) was washed through the sludge, these ammonia compounds would come off with the water and the resulting sludge had a very much smaller coagulant demand. Since the conditioner-grabbing substances were water soluble, the more you wash a sludge, the greater should be the savings in coagulant. This is true up to a certain point, beyond which the savings of chemicals becomes out of balance with the amounts of water required.

Actually, plant effluent has been used successfully in place of water, provided its alkalinity were low. The alkalinity needs to be low since these chemical-grabbing ammonia compounds are more soluble in this type of wash water. In dissolving they increase the alkalinity.

This washing out process, then, is elutriation. What does it do? As previously shown, it decreases the amount of chemical conditioner required for vacuum filtration. Many plants using elutriation report a more rapid filtration of the sludge. Sludge elutriation alone, without the use of chemicals, has been shown to produce a better settling, more compact sludge[3].

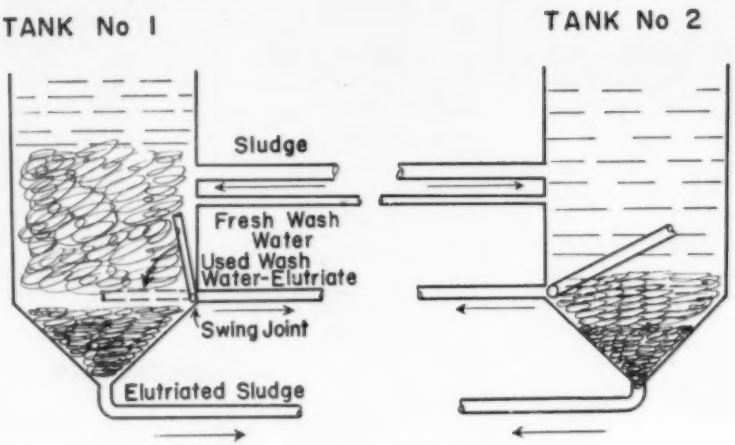


Fig. 1—BATCH process elutriation, using tanks alternately

Methods of Elutriation

Mechanically, several variations of the foregoing process are possible. The elutriation can be done either on a "batch" basis, or a "continuous flow" arrangement.

In the batch process, at least two tanks are required. The sludge is run into the first tank, the wash water is added, and the contents are thoroughly mixed. The mixture is allowed to separate and then the separated portions are drawn off as sludge and elutriate. While the sludge is settling, the second tank is filled, the water added, mixed, and settled. By this time, the first tank is ready to repeat the entire process with a new charge of sludge (see Figure 1).

In a continuous flow arrangement, the entire process occurs in a single tank, in the same manner as sedimentation takes place in a primary or secondary tank. There is an inlet for the sludge, one for the water, a zone of intense mixing, followed by a quiet zone for settling. Again, the end products are a more compact sludge with a smaller coagulant demand, and a liquid portion, both of which need disposal or further treatment (Fig. 2).

To reduce the amount of fresh wash water required in a continuous flow tank, combinations of two tanks may be used for countercurrent elutriation. For this scheme, the sludge and wash waters flow in opposite directions; that is, the unwashed sludge first meets water that has already washed other sludge. As the sludge moves along, it meets fresher water, until at the end of the system the now washed sludge meets the fresh water entering the tank. In other words, the unwashed sludge and the fresh water enter at opposite ends (Fig. 3). After settling, the end products are again the same—a more concentrated sludge and the used wash water.

Elutriation is a practical, workable aid in the sludge disposal problem. It has been used in many treatment plants throughout the country. Just as in every sewage treatment situation, an economic balance must be maintained between the benefits obtained and the cost of these benefits. Phelps[4] has said, "The capital and operating costs of these auxiliary devices (sludge elutriation) must be balanced against the savings in chemical conditioning. The return of elutriation water to the influent of the plant adds to the B.O.D. and solids loads and may further complicate the treatment of the sewage." This statement implies a caution for the treatment works designer as well as the operator. In other words, elutriation must be a planned, integral part of the plant, and not just something stuck in on the spur of the moment.

Factors in Good Practice

Before investigating actual plant results, several of the factors involved in good elutriation practice should be discussed. Elutriation has been tried on fresh raw sludge, old raw sludge, and digested sludge. These have been composed of primary sedimentation sludge alone, mixtures of primary and excess activated sludge, and activated sludge alone.

Genter[2] has shown that due to the digestion process the amounts of ammonia and related amino compounds (these are the coagulant-grabbing substances) are greater in digested sludge than in raw fresh sludge. Since this is so, the relative values of elutriation can be tabulated as follows:

Type of Sludge	*Coagulant Demand*	*Value of Elutriation*
Fresh raw sludge	Least	Greatest
Old raw sludge	More	Less
Digested sludge	Most	Least

The liquid used for elutriation is important. The lower the wash water is in alkalinity, the more effective it will be. A value of 100 ppm alkalinity or less is desirable.

Early experimenters and plant operators used river or lake waters. In many instances, however, this meant either an additional cost for equipment and pumping, or a heavier hydraulic load on the treatment plant, or both.

Later users tried their sewage plant effluent. If the effluent was low in

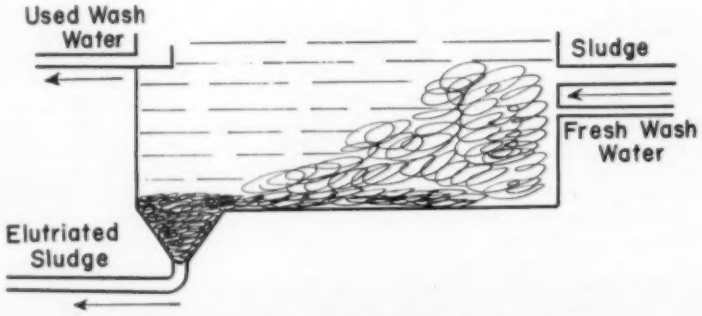


Fig. 2—CONTINUOUS flow elutriation, using single tank

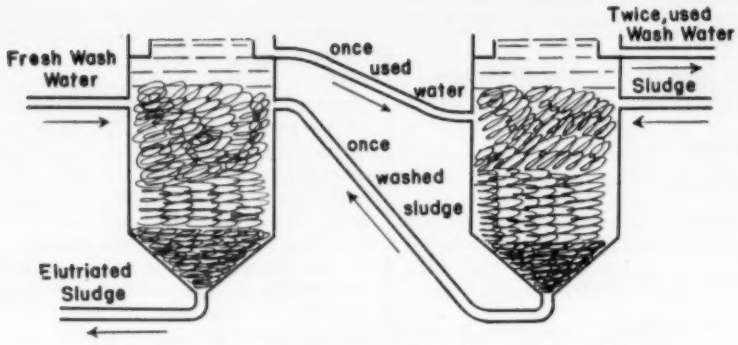


Fig. 3—CONTINUOUS countercurrent flow elutriation using two tanks

alkalinity, this wash water proved effective at lower cost. In some plants it is possible to arrange at least a partial gravity flow system, thus again reducing the pumping costs.

It should be emphasized that where elutriation is used, care must be taken that the additional load due to the wash water pick-up of solids and B.O.D. does not overload a treatment plant.

By careful planning, however, the additional volumes of liquid may be of benefit in some plants due to the diluting effect upon the strength of the raw sewage.

One of the questions that may arise in the operator's mind is, "How much wash water shall I use?" Although the ratio of elutriating water to wet sludge differs from plant to plant, it is commonly assumed that a ratio of 2 or 2.5 volumes of water to 1 volume of wet sludge is a good starting point for a trial in any plant. Why do the ratios vary?

The amount of wash water used depends upon many factors, among which are:

1. What kind of sludge is to be elutriated—raw, digested, primary, secondary, activated or combination?
2. What is the alkalinity of the wash water, and that of the sludge?
3. What is to be done with the sludge after elutriation?
4. How much sludge is to be handled each day?
5. What is the economic point; that is, how much alkalinity should be removed, balanced against the savings derived?
6. How much additional load is the wash water pick-up imposing on the plant?
7. How much detention time is available in the existing plant, or how much additional tank capacity is required.

These factors are interrelated, some working in one direction, some in the opposite. It is agreed that the lower the alkalinity of the wash water, the more times the sludge is washed, the longer it is washed—all these will reduce the coagulant demand and result in a better conditioned sludge. On the other hand, they lead to a greater pickup of B.O.D. and solids in the wash water, greater pumping costs, and require more elutriation and settling tank capacity.

How is an operator to combine these factors into a workable formula? The best answer is to investigate and experiment with his own plant sludge, with the available wash water, and utilizing his own plant facilities. However, as a guide in this direction many plant and laboratory reports have been published (and are included in the references at the end of this article).

Keefer and Kratz[5] have data and charts on various types of sludge and washings; Table 1 is an example of their results. McNamee[6] has published charts showing relative doses of ferric chloride for various degrees of elutriation. He has shown that the amount of ferric chloride required is proportional to the alkalinity of the sludge and sludge liquor. Since elutriation washes out the alkalinity, the more times a sludge is elutriated the smaller the amount of ferric chloride required. From one series of his experiments he has concluded that digested sludge elutriated by countercurrent washing with 2.5 volumes of water can be conditioned with one-third the amount of ferric chloride required if not elutriated.

Craemer[7] reports the results of three years of elutriation experience at the Hartford, Conn., plant and reports, among other things, that elutriation has (a) effected savings in digestion time, (b) eliminated sludge filtration odors, and (c) resulted in a longer life for the filter cloths, as shown in Fig. 4.

Others have published plant results from time to time which can be found in the literature. Two of the most recent are those of Fraschina[8] at the Richmond-Sunset plant at San Francisco, Calif., and Sparr[9] at the East Rockaway, N. Y., plant. Fraschina apparently is very well pleased with elutriation. Sparr presents certain formulas to relate the quality of the elutriation tank effluent and three factors—the dry solids loading, the volatile content of the sludge, and the liquid detention time. Among the results of his plant-scale study he cautions that the quality of the elutriator effluent be "seriously considered if detrimental high solids recirculating loads are to be avoided."

In an attempt to formulate the coagulant requirements for sludge elutriation, Genter[10] combined the liquid portion and solids portion requirements. His equation may be written:

Use of Equation

To illustrate how the foregoing equation is used, assume a sludge, be-

TABLE 1

Elutriation of Digested Thickened Sludge

Vol. of Wash Water	Ferric Chloride[a]	Filter Capacity[b]	Saving
0	6.0	10.2	—
1	6.0	26.6	2.6 × filter capacity
0	4.7	5.9	—
3	4.0	28.8	5 × filter capacity with 15 percent less coagulant
0	5.4	8.0	—
3	1.6	8.0	70 percent less coagulant

[a] Pounds $FeCl_3$ per 100 pounds dry solids in sludge
[b] Pounds dry solids in cake per square foot of filter area per hour

$$\% \text{ chemical } (FeCl_3) = 1.08 \times \frac{0.0001 \times \text{alka. sludge moisture (ppm)} \times \% \text{ sludge moisture}}{(1 - \% \text{ sludge moisture}) \text{ or } (\% \text{ total solids})} + 1.6 \frac{\% \text{ volatile matter}}{\% \text{ fixed matter}}$$

All these values are on a dry basis. In terms of the usual sludge analysis this equation may be somewhat simplified to:

$$\% FeCl_3 = 0.000108 \times \text{alkalinity (ppm)} \times \frac{\% \text{ water}}{\% \text{ solids}} + 1.6 \frac{\% \text{ volatile}}{\% \text{ ash or fixed}}$$

Fig. 4—GENTER method of calculating coagulant requirements

fore elutriation, of 4 per cent total solids and 55 per cent volatile solids having an alkalinity of 3,000 ppm. After elutriation, the alkalinity has been reduced to 250 ppm. How much (%) $FeCl_3$ is required before and after elutriation?

If 4% total solids, then (100% — 4%) = 96% moisture.

If 55% volatile solids, then (100% — 55%) = 45% fixed solids.

$$\% FeCl_3 = 0.000108 \times 3000 \text{ ppm} \times \frac{96}{4} + 1.6 \frac{55}{45}$$

$$= 0.000108 \times 3000 \times 24 + 1.6\ (1.22)$$

$$= 9.73\%$$

$$\% FeCl_3 = 0.000108 \times 250 \text{ ppm} \times \frac{96}{4} + 1.6 \frac{55}{45}$$

$$= 2.60\%$$

It must be pointed out that the equation is only a guide for the operator. He must determine the best dosage for his particular situation. Some of the factors will be:

1. Amount of alkalinity removed by elutriation.

2. Type of sludge to be filtered, as previously discussed (raw or digested; primary, secondary, or combinations).

3. Whether the sludge contains any industrial wastes that react with the coagulant (iron reducing compounds, mineral or cutting oils, etc.).

4. What degree of dewatering is expected of the filter (% moisture in the cake).

5. Operation of the filter (speed of revolution, type of filter cloth, etc.).

6. The coagulant used (ferric chloride, alone or with lime; chlorinated copperas, ferric sulfate, etc.).

7. If digested sludge, the degree of digestion is important (% vol./% fixed).

As a first attempt at determining how much wash water is to be used, the formulas of Genter[11] can be used. If single-stage elutriation is used the ratio, R, of wash water to sludge is:

$$R = \frac{D - E}{E - W}$$

For any number of stage washings, *n*, (more than 1), the ratio for each wash is:

$$R = \sqrt[n]{\frac{D - W}{E - W}} - 1$$

For countercurrent washing (two tanks), the ratio is:

$$R = \sqrt{\frac{D - E}{E - W}} + .025 - 0.5$$

in which

D = alkalinity of the sludge before elutriation;
E = alkalinity of the elutriated sludge;
W = alkalinity of the elutriating (wash) water or effluent; and
R = ratio of volumes of elutriating water to the volume of moisture in the sludge.

In the foregoing formulas R is the ratio of the volume of water to the volume of moisture in the sludge. The operator, however, wants to know the volume of water to the volume of sludge (not moisture). Therefore, R must be multiplied by the fraction of water in the sludge.

Incidentally, much has been said regarding the alkalinity of the sludge. How is this determined in the plant? The standard method for running sludge alkalinity is given on page 349 of the Tenth Edition and page 158 of the Ninth Edition of "Standard Methods"[12]. While this is a relatively simple procedure, the end point of the titration may be somewhat difficult to see at first.

With practice, though, any operator soon will be able to detect the correct end point. A fluorescent light over the titration will help, as will doing the titration over a white table top. If a pH meter is available, this can be used to indicate the titration end point with no need to watch for color changes.

The foregoing discussion has been concerned primarily with sludge elutriation as an aid in conditioning sludge for vacuum filtration. Recently, interest in elutriation has been revived as a means of sludge thickening and as an aid in two-stage digestion. These will be discussed in the next article of this series, "Recent Advances in Sludge Digestion."

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Vacuum Filter Blankets

by WARREN L. SHEDDEN

Asst. Mech. Engr., West-Southwest Sewage Treatment Plant, Chicago, Ill.

IN A SEWAGE disposal plant where sludge is dewatered to produce filter cake for further drying, the filter room may be considered the heart of the plant. Years of study and endless trials are required to establish methods of sludge conditioning so that a continuous production of filter cake can be maintained.

In the filter room characteristics of the incoming concentrated sludge are closely observed and noted. Conditioning treatment is altered as required to maintain a constant level of filter cake for effecient plant operation and for dried sludge (fertilizer) production.

At the West-Southwest Sewage Treatment Plant of the Sanitary District of Chicago, excess sludge from the activated sludge sewage treatment process is first filtered on vacuum filters, and then is dried by flash dryers and is disposed of in bulk as a fertilizer base. The original plant design contemplated filtration, drying and incineration of sludge from both preliminary settling units and secondary clarifiers. Difficulties in the sludge drying system, caused by the high grease content of the preliminary sludge, after about seven months of operation led to adoption of the present method of disposal.

Filter Installation Grows from 24 to 98 Units

Originally twenty-four filters 11 ft. 6 in. in diameter by 16 ft. in length were provided. These were arranged in eight rows of three filters each. Each line of filters discharged to a rubber belt carrying the filter cake to a drying system. In 1940, after about a year of operation, another filter was added to each row.

During 1953, three additional filters were added to each of the original lines, and six new lines of filters (seven filters in each) were installed. This installation brought the total number of filters to ninety-eight. The new facilities were available for service in November, 1953.

Ferric chloride is used to condition the sludge. By conditioning, the sludge is concentrated from about 0.8 per cent solids (as wasted from the final settling tanks) to 1.2 to 2.0 per cent solids as delivered to the filter room). The pH range of the treated sludge is approximately 3.0 to 4.0, varying somewhat with the volatile matter content of the sludge. The pH of the conditioned sludge varies inversely with the quantity of ferric chloride required to properly condition the sludge. *It is essential that the sludge be properly conditioned in order that the blankets can efficiently produce the desired filter cake.*

Filter Blankets Are Important

The capacity of a sludge drying system is largely determined by the moisture content of the filter cake delivered to it. Accordingly, one of the most important factors in vacuum filter operation and cake production is the selection, installation and care of the filter blankets. Filter blankets serve the purpose of removing liquid from the sludge solids, to produce a filter cake for further drying. This plant has endeavored to obtain the best possible filter cloths for its use. To that end, extensive studies have been made of all factors, including use of different kinds of blankets and methods of installation, treatment and maintenance. The original filter blankets were napped wool twill, weighing 12 ounces per square yard of material. They were stretched tightly over ¼-in. mesh 16 gauge monel metal screening which was fastened on wood grids nailed to the decking. Twelve gauge copper or copper alloy wire was spirally wound around the drums using two-inch spacing. The cake was removed, after blowback, by a heavy steel scraper blade. The blade was welded to the apron of the filter unit and was pulled tightly against the winding wires.

The maintenance of this system of cloth mounting was high, because of corrosion, wearing and breaking of the winding wires, and through corrosion of the monel screen. The unavailability of monel metal screen brought about the substitution of wood for backing grids, which provided drainage and served as support of the filter cloth.

Wood Supports for Blankets

The face of the wood grids was ribbed on ⅜-inch centers, with a groove depth of ¼-inch. The back of the grids was cut to provide drainage channels, directioned both laterally and circumferencially. Communication with the face of the grid was accomplished by wide saw cuts (approximately ⅛-inch), running in a horizontal direction, and deep enough to reach the grooves of the face. These cuts also served to accommodate the sections to the curvature of the filter drum.

The wood sections were of a length to fit between the separator strips which divide the circumference of the drum into twenty-four sections of approximately twenty inches each. The ribbing was set at an 18-degree angle to the separator strips, in order to keep the winding wire out of the backing grooves.

With restrictions on the use of strategic metals during the last war, it became apparent that an insufficient supply of copper wire would hamper operations. Experiments were made to fasten the cloth to the separator strips. This was first accomplished by grooving the separator strips and holding the cloth in place with nailed wood strips which forced a tight fit of the cloth in the groove. A shoulder cut into the backing around each end of the filter allowed similar end fastening of the cloth.

A Stainless Steel Scraper and Plastic Panels

The scraper blade was then held against the cloth only by a weighted bar at each end; its travel was limited by set screws, to insure its clearing the retaining strips at the panel separators. Somewhat later, an 8-inch strip of 22-guage stainless steel was bolted to the apron with a five-inch extension. This strip was used in place of the stiff steel scraper blade. The set screws to adjust the floating arrangement were continued. Present replacements are made of 16-gauge stainless steel, which has longer life, holds alignment better, and exhibits less tendency to sharpen at the scraping edge.

Injection-molded polyvinyl chloride plastic panels are now used for backing grids, with the ribs vertical to the separator strips. The cloth is held in place by acid-resistant cord driven into dovetail mortises cut in the separator strips. The ends of the panels are sealed by tightly drawn stainless steel ribbons, nailed at intervals to prevent slipping.

In addition to the savings in materials, our present panel fastening has resulted in reduction of time required to replace blankets and make repairs. The response of the blankets to water wash and to detergent wash has been improved, and the cleaning of the backing at the time of cloth changing

TABLE I
Comparative Rating of Vacuum Filter Blanket Materials

Material	Installation Rating	Initial Cake Pickup	Cake Production	Elongation Tendency	Water Wash Response	Detergent Wash Resp.	Acid Wash Resp.	Scraper Abrasion Resistance	Useful Life (Hrs. of Service)	Economic Rating
Wool 12 ozs.	Difficult	Poor	Fair	Too Much	Good	Good	Good	Poor	1900	
Wool 13 ozs.	Difficult	Fair	Fair	Too Much	Good	Good	Good	Fair	2400	
Wool 14-15 ozs.	Easy	Very Good	Very Good	Much	Good	Good	Good	Good	2700	4
Wool 16 ozs.	Difficult	Fair	Fair	Much	Good	Good	Good	Good	1600	
Wool Treated 14-15 oz.	Easy	Very Good	Very Good	Some Varied	Very Good	Very Good	Very Good	Good	3300	3
Vinyon	Very Difficult	Fair	Fair	Too Much	Fair	Poor	Poor	Poor	1000	
Nylon 100%	Very Difficult	Fair	Fair	Much	Fair	Fair	Very Poor	Good	800-7600	
Nylon 90% Saran 10%	Very Difficult	Fair	Fair	Much	Fair	Fair	Poor	Good	3000	
Nylon 25% Wool 75%	Easy	Good	Fair	Some	Good	Good	Poor	Good	3300	
Dynel 50% Wool 50%	Easy	Good	Good	Some	Good	Good	Good	Good	3700	
Orlon 100%	Difficult	Fair	Good	Some	Good	Fair	Poor	Fair	2000	
Dynel 100%	Difficult	Poor	Good	Some	Good	Good	Good	Fair	Over 4000	2
Dacron 100%	Easy	Very Good	Very Good	None	Very Good	Very Good	Very Good	Very Good	Over 11,000	1

is much easier.

The change from wire winding to panel fastening of the filter cloth accelerated our studies of filter blankets. With support every two inches by the winding, little ballooning effect was possible at the time of the blowback; however, a certain amount was desirable to effect contact of the scraper blade with the filter cloth for proper cake removal. Abrasion effect was a much smaller factor.

With the panel fastening, an area of wet cloth approximately twenty inches in one direction and sixteen feet in the other, was exposed to the blowback air pressure.. There was evidence of excessive elongation of the cloth in both directions. One remedy lay in reducing the blowback air presure from eight pounds to two or three pounds per square inch; at the same time, cloth with lower elongation propensity was sought. Studies showed the larger benefit would be derived from an increase in the number of twists given the threads used, and from a slightly closer weave, resulting in a slightly heavier cloth.

Installing Filter Blankets

In our studies of filter cloths, we made it a practice to give no special care to any cloth during the program, since it was necessary to discover its value for use under ordinary operating conditions. In making the installation, cloths are fitted snugly to the filter drum, with tension maintained as evenly as possible. A dark colored woof thread woven into the cloth at about four feet intervals (as measured along the warp) greatly aids in aligning the blanket. The degree of tension required varies with the material and the weave of the cloth, to allow for differences in stretch while in service.

The blankets as purchased are about 16 inches longer and six inches wider than the actual measurements of the drum, to make installation easier. The trimmings are used for patching cloths torn in operation.

Detergent Wash

After installation, the blanket is given a detergent wash to thoroughly wet and flex the fibers. For the detergent wash we add two quarts of 60 per cent active triethanol amine alkylaryl sulphonate, to about three hundred gallons of water in the filter pan. The drum is rotated for four hours with the agitator in operation; this provides a foamy suds washing action, cleaning out most of the accumulation of solids, greases and fungi which cause blanket blinding. A plain water rinse follows, using the jet sprays mounted at the rear of the filter.

During filter operation, the cloths became loaded with sludge solids, grease and iron oxide. In warm weather there also are fungus growths from the conditioned sludge which cause blinded areas on the filter blanket. Each filter is water-washed after a forty-eight hour period of service. When this washing fails to clean the filter satisfactorily, detergent wash, as previously described, is used. Detergent wash usually will remove solids, grease and fungus, but will not effect iron oxide.

Acid Wash

If unsatisfactory cake pickup indicates excessive iron oxide clogging, the cloth is washed with 18° Beaumé inhibited muriatic acid, which is dripped on the blanket at the top of the slowly revolving drum. Approximately 12 gal. of acid are applied.

The acid is allowed to remain in the blanket for about eight hours, with the filter drum revolving continuously. The filter blanket is then sprayed with water for about an hour before the filter unit is returned to service. When less than 75 per cent of the area of the blanket fails to produce filter cake, it is marked for replacement.

Service Record and Testing

A complete record is maintained for all blankets, showing information such as purchase contract, manufacturer, date received, blanket number, date installed, kind of material, weave, weight, pressure loss, wash and maintenance record, hours of service, date and reason for replacement.

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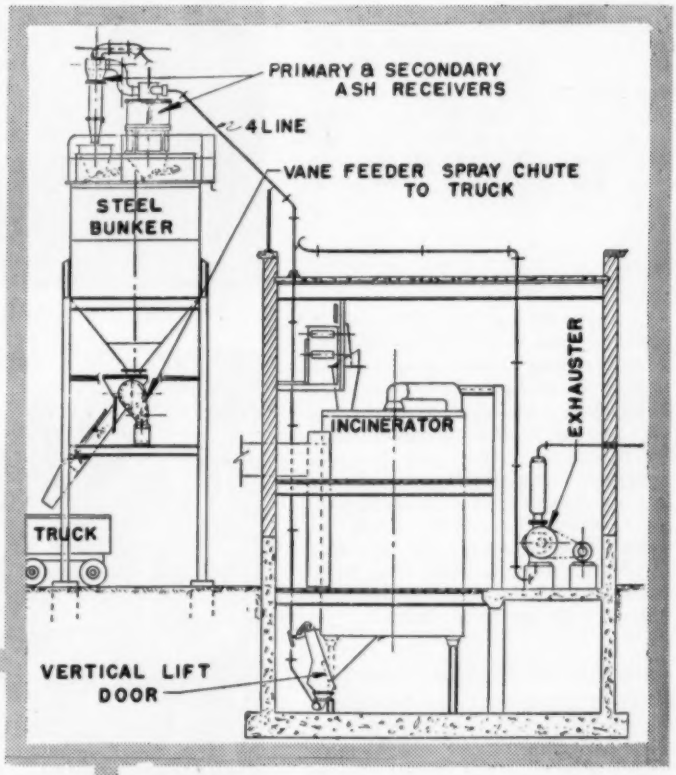
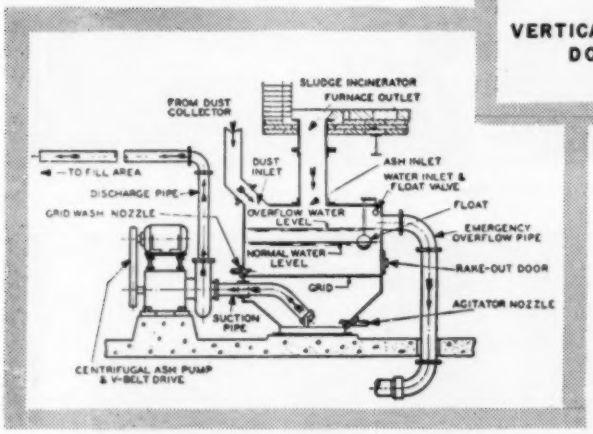
Beaumont

HYDRAULIC AND PNEUMATIC CONVEYING EQUIPMENT FOR HANDLING INCINERATED SLUDGE

The pneumatic conveyor system shown at right was engineered and manufactured and installed by Beaumont Birch for the West Sewage Treatment Plant at Williamsport, Pa.



A hydraulic system as shown in drawing below was furnished for the Bay City, Mich., sewage treatment works.



Beaumont Birch also manufactures mechanical equipment for conveying filtered sludge to the furnace and dried or incinerated sludge from the furnace.

RECENT CONTRACTS FOR HANDLING DRIED OR INCINERATED SLUDGE

USING HYDRAULIC CONVEYING EQUIPMENT

Bay City, Michigan
Nichols Herreshoff Furnaces
Francis Engineering Co., Consultants

Indianapolis, Indiana
Nichols Herreshoff Furnaces
Moore & Heger, Cons. Engrs.

USING PNEUMATIC CONVEYING EQUIPMENT

Williamsport, Pa.,
West Plant
Nichols Herreshoff Furnaces
Chester Engineers, Consultants

Atlantic Refining Co.
Philadelphia, Pa.
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Beaumont BIRCH COMPANY

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DESIGNERS — MANUFACTURERS — ERECTORS BULK MATERIAL HANDLING SYSTEMS

A sample of each blanket, as installed, is filed for possible future reference, and a second sample is sent to the laboratory for testing. There it is examined for conformity to specifications, including pressure loss, which is measured in inches of water at an air flow of 150 cu. ft. per minute per sq. ft. of blanket area. This standard was adopted instead of the A.S.T.M. designation D 461-47 (which defines permeability as the quantity of air passed in cu. ft. per minute per sq. ft. at 0.5 inch pressure loss), since it was found that the slope of the curve plotting pressure loss against air flow varied among the different types of materials.

The sanitary district's testing equipment consists of a source of low pressure air, a plenum chamber having a circular opening of 0.1 sq. ft. area, a zero to 2.0 inches inclined pressure gauge measuring to 0.01 inch, and an orifice flow meter. The filter cloth is clamped over the circular opening of the plenum chamber by means of a ring. Air flow and pressure measurement are recorded for a sufficient number of settings to permit plotting a curve of the results. The pressure vs. air flow curves for various filter cloth materials may then be compared, and correlated with operating data.

Specific Cloth Qualities Needed

There are several specific qualities in a filter cloth which fit it to serve well under the severe conditions to which it is subjected. Among the desirable qualities are:

1. Good pliability, toughness, snag and abrasion resistance, with a minimum tendency to stretch. These qualities are necessary for satisfactory installations, and for efficient service.

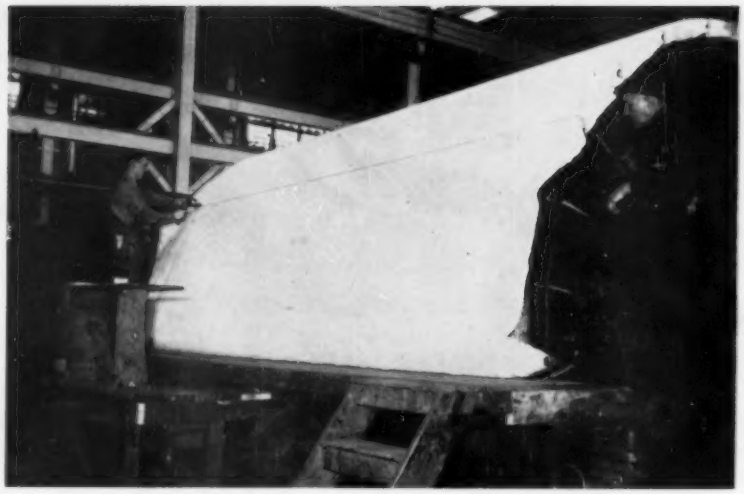
2. Long nap. A nap of ½-inch or more helps to seal the blanket surface, to pick up the proper amount of sludge and to stand the wear caused by contact with the scraper blade.

3. Suitable pressure loss.

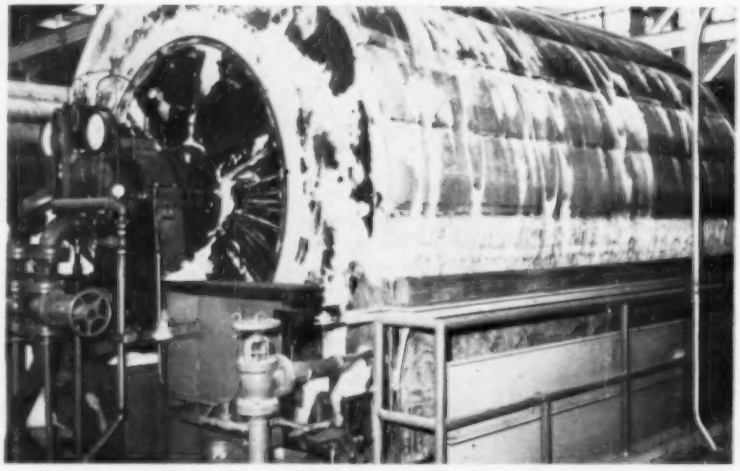
4. Resistance to chemicals used in conditioning the sludge and in acid washing blankets.

During the fifteen years of filter operation, eleven different blanket materials have been used and studied. These are: Cotton, Untreated Wool, Treated Wool, Vinyon, Nylon, 90% Nylon-10% Saran, 25% Nylon-75% Wool, Dynel, 50% Dynel-50% Wool, Orlon, and Dacron.

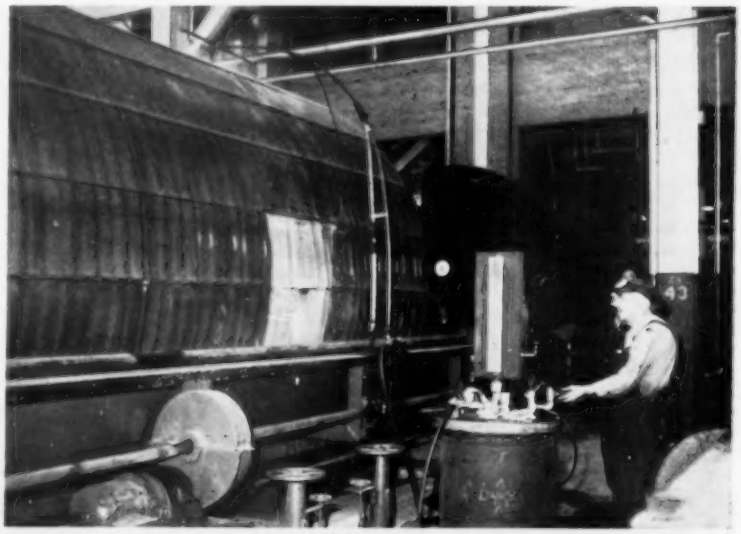
The weight of blanket materials has varied from 12 to 16 ounces per square yard. Some were napped and



INSTALLATION—Acid-resistant cord, driven into mortise, fastens blanket



DETERGENT WASH—Removes solids, grease and fungi causing blinding



ACID WASH—Muriatic acid treatment removes the iron oxide clogging

others not. The various cloths, except cotton, are rated in Table 1 with respect to factors considered of importance in blanket use under conditions applying at The West-Southwest Sewage Treatment Plant.

Summary of Operating Experience

Cotton

The few cotton filter blankets used during the early years of our plant operation were too expensive, considering their short life and frequent wash requirements. None have been used since panel mounting of filter blankets was adopted.

Wool, Untreated

Untreated wool twill blankets have been our general filter service cloth throughout most of the entire period of operation. All have been long napped, and installed with the nap lying the opposite direction of the drum travel. All were satisfactorily pliable, and all continued to stretch through service. With increasing weight (up to the 14-15 ounce type) the characteristics of the blankets improved. The 12-ounce blankets gave poor initial filter cake pickup. They required pre-service treatment, and frequent washings during service before desired filter cake delivery was obtained. The 16-ounce type blankets were too heavy, as they proved difficult to install and produced a low cake yield. They required too much care to be worthy of extensive study.

The pressure loss measured for the wool cloths (in inches of water) were: 12 ounce, 0.31 to 0.38; 13 ounce, 0.50 to 0.70; and 14 to 15 ounce, 0.45 to 0.80. Pressure loss data on the 16-ounce cloth are not available. The useful life of the 12, 13, and 14 to 15-ounce cloths averaged 1900, 2400, and 2700 hours respectively; However, a few blankets in each class did much better than the average.

Wool, Treated

During warm weather fungus growths clog the interstices of the cloths and tend to fill the backing grooves and drainage channels. In addition, filter blankets out of service for extended periods of time deteriorate as a result of microbial action. To combat this condition, washes of chlorine water, bromine water, pentachlorphenol solution and copper sulfate were used, but with very little improvement. The use of bromine water was very hazardous to the operating personnel.

It was found possible to have the blankets treated at the mill, using a permanent type of bactericide, either before or after weaving. While some blocking of the cloth interstices was occasionally in evidence, the overall results with fabric as treated were satisfactory, and the blanket life was noticeably increased. Pressure loss for these blankets ranged from 0.40 to 0.60 inches, and their service life averaged 3300 hours. Elongation was present throughout service, but was measurably lower than that of the untreated wool cloths. Purchase contact specifications for these treated cloths, used during the past several years, are as follows:

"The weave to be two up and two down, straight twill, with a thread count of approximately thirty-one (31) end warp and twenty-five (25) end woof.

"The material to be all wool, weighing not less than 14½ ounces per square yard, exclusive of wool fat and bactericide; and woven in one continuous piece without seams and one side long napped. The amount of nap to be approved on sample submitted before fabrication. The wool to contain no noils, card fly, card strippings, card waste or reused wool. Garnetted wool not to exceed 25%.

"The warp and woof thread to be twisted 105 turns per foot, and the cloth to be finished in a manner to produce a minimum of stretch in the width. At approximately every 36 to 48 inches as measured along the warp, a woof thread of a dark, distinctive, permanent dyed color will be inserted, to aid the mechanics while installing the cloth.

"The cloth to have sufficient permanent bactericide treatment to protect it throughout its useful filter life. The treatment should add approximately 2½% to the weight of the untreated cloth."

Vinyon

The Vinyon cloths used were not satisfactory, partly because of the type of weave, which presented installation problems and stretching during service; but of more serious consequences, because its poor resistance to acid washing. These cloths were removed after an average of about 1,000 hours of filter blanket service.

Nylon

Highly variable results were obtained with nylon cloths; some had nap, others had to be napped with wire brushes. One or two blankets gave several thousand hours of satisfactory service and stood washing with 17½% muriatic acid. Others deteriorated or glazed when washed with 5% to 7½% muriatic acid, and most of them responded only fairly well to detergent wash. The glazing action appeared to be a partial solution of the fiber with re-precipitation, resulting in a badly clogged cloth having a glazed surface.

The material is durable and abrasion-resistant, with very little dry stretch, but many blankets showed excessive stretch while in service. However, testing is being continued on blankets in the 0.80 to 1.20-inch pressure loss range. It is because of the wide range of results obtained from this material that we have been unable to establish any set program for wash and acid treating, with any degree of assurance that the blanket will be serviceable after treatment.

Nylon 90%—Saran 10%

In appearance this combination of cloth resembled the 100% Nylon, but because of the Saran content it became brittle in use, requiring almost daily repairing. It was stiff and bulky, difficult to install. Its reaction to acid washing was similar to that of the 100% Nylon cloths. The pressure loss was 0.74 inches.

Nylon 25%—Wool 75%

This combination of materials is similar to wool in appearance, handling and service, but because of the nylon content it had poor resistance to acid washing. It showed excessive elongation. The pressure loss was 0.62 inches.

Dynel 50%—Wool 50%

This combination was rather bulky, but pliable; pressure loss was 0.90 inches. It withstood scraper abrasion well and responded to all types of treatment, but it stretched in service as badly as 100% wool cloth. It was a quite satisfactory material.

Orlon 100%

This material was very soft and pliable, in appearance it resembled Nylon. The pressure loss was 1.70 inches. It delivered a desirable filter cake but blinded easily. The poor acid resistance of the cloth, and its poor response to detergent washing limited its useful filter life to about 1,000 hours, and its overall use to about 2,200 hours. This material, like Nylon, deteriorated or glazed when acid washed.

Dynel 100%

The studies have included one Dy-

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Featured by: high burning rates because of the well-vented stationary cone and revolving stoking arms; no dead space corners; charge dropping on cone assumes similar shape, well aerated for combustion; continuous mechanical stoking; single charging and single ash removal opening; entire unit accessible from outside; can be combined readily with rectangular combustion and expansion chambers, providing maximum operating flexibility.

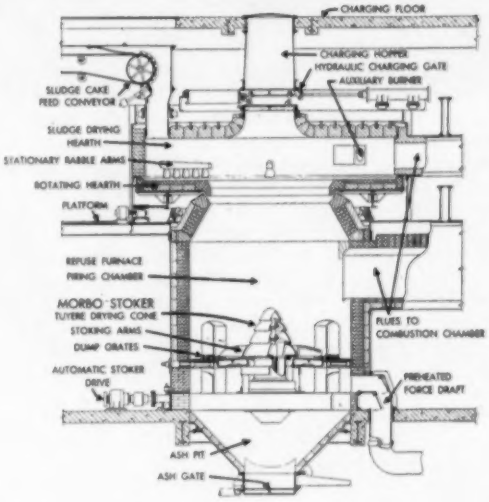
We suggest that you discuss your disposal problems with our engineers as they may involve complex factors where our broad experience would be helpful.

Close up of cone showing fixed inverted 'bowls' and revolving stoker with arms.

Modern Incinerator Plant equipped with four Morse Boulger Mechanical Stokers (Hempstead, N. Y., Henry W. Taylor, Cons. Eng.)

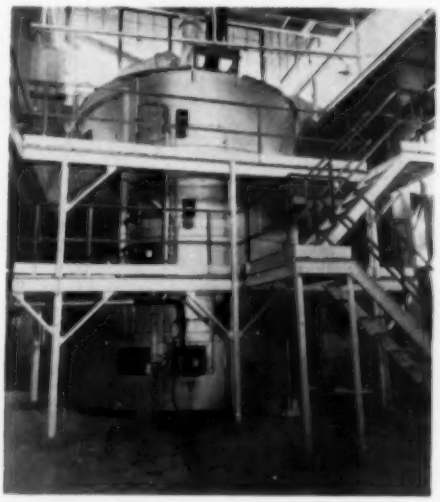
COMBINATION SLUDGE REFUSE INCINERATOR

This type unit is ideal for the smaller community which must dispose of sewage sludge as well as municipal refuse. The sludge is dried on the upper hearth and then rabbled (stationary arms and revolving hearth) into the lower chamber where it is incinerated with the refuse. Very compact plant and economical in both first and operating costs.



MORSE BOULGER MULTIPLE HEARTH FURNACE

Designed to dehydrate or incinerate sewage sludges and many kinds of industrial wastes. Material is rabbled inward and outward as it passes downward from hearth to hearth. Provides maximum pre-drying and incinerating capacity, discharging dry ash from wet sludge feed.



nel blanket having a pressure loss of 1.75 inches, and three in the range of 0.31 to 0.45 inches. The denser cloth was bulky and stiff, difficult to install. The others were more loosely woven, softer and more pliable, and of satisfactory consistency. However, none gave outstanding performance. There was very little stretch during service, and they were responsive to acid and detergent washings, but were not as resistant to scraper abrasion as was desired.

Dacron 100% (Polyester Fibre)

This material is tough and strong, pliable, abrasion-resistant and dimensionally stable. It is acid-resistant, and seems to be water-repellent and rot-resistant. We have twenty-four 100% Dacron filter cloths in service, and the above qualities are outstandingly noticeable in each case. The pressure loss of the Dacron blankets ranges from 0.50 to 1.61 inches. The material has a satisfactory nap and practically no stretch during service. It responds very well to all types of wash treatment.

At present it appears that these cloths are most satisfactory for our use, and will be adopted as our general service filter cloth. They rate high in all respects, and their toughness and durability is outstanding. One filter blanket is in excellent condition after over 11,000 hours of filter service, another has had over 7,000 hours, and several have had over 4,000 hours. None has been patched or repaired in any way, and all continue to give satisfactory filter cake production. No cloth of this type is showing signs of abrasion wear or deterioration from decay.

It is expected that many of these cloths will duplicate or better the outstanding performance of the original test blanket. The use of Dacron on the ninety-eight filters in service will greatly improve operations and reduce our blanket maintenance costs.

Three Important Considerations

The vacuum filtration of sewage sludge imposes severe conditions on the filter blanket. If the blanket is to serve satisfactorily, the cloth must be properly selected, installed, and maintained. In summary:

Selection. Material selected for a vacuum filter blanket should be:

- Tough, strong and pliable.
- Abrasion resistant and dimensionally stable.
- Of suitable pressure loss.
- Of long nap, at least one-half inch long.
- Acid and chemical resistant.

Proper Installation. For proper installation:

- The blanket should be of material that can easily be installed with proper tension and alignment.
- The material should exhibit a minimum dry stretch during installation, as well as a minimum stretch during its service life.

Care. The blanket material should:

- Respond well to water and detergent wash, acid wash, and chemical treatment, without any noticeable injury to the fabric.
- Throughout the service life of the filter cloth, be kept as clean as possible. A clean and pliable cloth will deliver a better filter cake, from a larger filtering area, and will have a much longer useful life.

Conclusions

In Table 1 the column headed "Economic Rating" is based on the original cost of cloth, the installation, repair and maintenance costs, and on the efficient cloth life. The designations 1, 2, 3, and 4 represent what are believed to be the best selections to meet requirements at the West-Southwest Sewage Treatment Plant of the Sanitary District of Chicago. Different conditions would, of course, call for modifications. Although Dacron cloths of the design specified best meet present requirements, the engineering staff of the Sanitary District of Chicago continues to investigate and experiment, always seeking improvements.

Acknowledgements

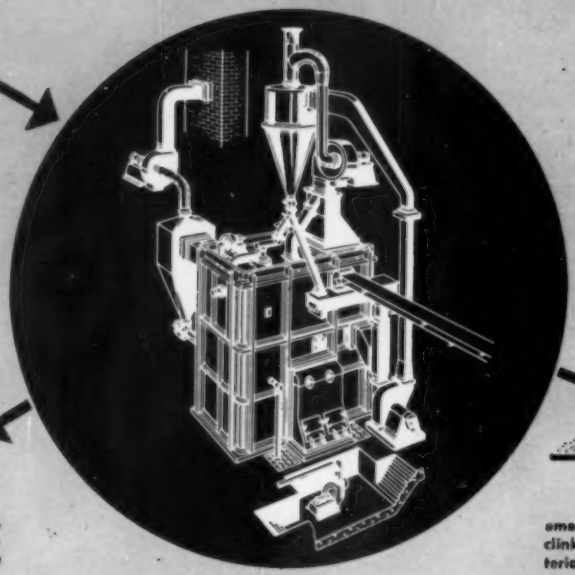
Design and research on all phases of sludge filtration and disposal for The Sanitary District of Chicago are under the direction of Wm. A. Dundas, General Superintendent; W. H. Trinkaus, Chief Engineer (on leave); H. P. Ramey Acting Chief Engineer; Langdon Pearse, Sanitary Engineer; F. W. Mohlman, Dircetor of Laboratories; C. P. McLaughlin, Engineer of Mechanical Design. Philip Furlong is Engineer of Maintenance and Operation. Operation of the West-Southwest Treatment Plant is under the direction of A. H. Goodman. Physical research and testing are under the direction of A.J. Beck, Senior Sanitary Chemist and C. G. Poindexter, Asst. Sanitary Chemist. J. W. Wade, Senior Civil Engineer, is responsible for correlating results of operation with specifications.

The C-E Raymond System —

the MODERN method of SLUDGE DISPOSAL

SLUDGE

as a vacuum filter cake or thickened sludge from any type of sewage treatment process enters the C-E Raymond System.



SOIL CONDITIONER

emerges as a desirable product, easy to handle, exceptionally rich in humus, and containing the trace elements found in good topsoil.

ASH

emerges as a fine dust, free from clinker and unburned organic materials.

and / or

The C-E Raymond System is the most popular . . . most versatile on the market today. It combines the principles of Flash Drying and Incineration in a single compact system that allows you to Flash Dry or Incinerate sewage sludge alternately or concurrently. It is available with a high temperature deodorization system that assures odor-free operation.

Flash Drying by the C-E Raymond System is a continuous process in which vacuum filtered sludge — if uncontaminated with undesirable industrial wastes — is efficiently heat dried to a marketable soil conditioner retaining all its original nitrogen, but eliminating the objectionable qualities of the original wet sludge. In a well designed and operated "activated plant" the revenue from the sale of soil conditioner is sufficient to cover a sizable part of plant operating costs.

Where the production of soil conditioner is not desired or the sludge is unsuitable, it is flash dried and then completely burned in suspension to an easily disposable, sterile ash.

The services of C-E specialists are available to help you plan for the end of atmospheric or stream pollution in your community, as has been done in so many others. For specific recommendations on the most practical answer to your sludge disposal problems, get in touch with the Combustion office nearest you.

C-E

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also flash drying and incineration systems for industrial waste disposal

UTILIZATION OF SEWAGE SLUDGE

BECAUSE sewage sludge contains a high percentage of organic and humus matter, much thought has been given to the use of sludge as a fertilizer or soil conditioner. In evaluating fertilizer characteristics of sludge, there are five types of sludge to be considered: Raw (primary), digested, activated, digested activated, and chemically precipitated. Analyses of various types of sludge are shown in the accompanying table.

Analysis of Various Types of Sludge*

Percent-Dry Basis

Constituent	Types of Sludge				
				Filter Cake	
	Raw	Digested	Act. Sludge	Raw	Digested
Volatile Material	60-80	45-60	62-75	55-75	40-60
Ash	20-40	40-55	25-38	25-45	40-60
Insoluble Ash	17-35	35-50	22-30	15-30	30-45
Grease and Fats	7-35	3-17	5-12	5-30	2-15
Protein	22-28	16-21	32-41	20-25	14-30
Ammonium Nitrate	1-3.5	1-4	4-7	1-3	1.3-1.6
P_2O_5	1-1.5	0.5-3.7	3-4	1.4	0.5-3.5
K_2O		0-4	0.86		
Cellulose, etc.	10-13	10-13	7.8	8-10	8-12
SiO		15-16	8.5		
Iron		5.4	7.1		

*Data from FSIWA MOP No. 2.

Perhaps the best known sludge sold as fertilizer is Milorganite from Milwaukee, Wis., although Chicago and other cities also sell activated sludge and a number of cities sell digested sludge. Marion, Ind., has sold digested sludge directly from digestion tanks without dewatering for delivery and application directly on farm land. Since the sludge is not dried the soluble ammonia nitrogen is not lost, as it would be on drying.

At best, any type of sludge is lacking in some respects as a complete fertilizer. As can be seen from the table, the nitrogen, phosphorous and potash contents are lower than those of commercial fertilizer, but the humus content is of value for soil conditioning. In addition, sludge contains amounts of trace elements and growth promoting substances of value to soil conditioning. These trace elements include copper, zinc, manganese and magnesium. Generally, it is considered that dried activated sludge is better than digested sludge and that raw sludge should not be used on soil, for fertilizing purposes, because of possible contamination of products grown therein.

Preparation of the dried sludge for sale is essential to increasing its salability. Heat dried sludge is pulverized to granular size during the drying. Open bed dried sludge must be disintegrated.

According to data collected by the U. S. Dept. of Agr., collected between 1936 and 1944 approximately 100,000 tons of dried sludge was used each year. The revenue to be obtained from the sale of sludge varies. In many cases, the revenue may not cover the cost of producing and selling the sludge, but this method may still be less costly than other methods of disposal. For a complete discussion of this subject, reference should be made to "Manual of Practice No. 2—"Utilization of Sewage Sludge as Fertilizer" published by the Federation of Sewage and Industrial Wastes Assn.

When adequate land area is available and the amount of sludge is relatively small, the problem of ultimate disposal of sludge is of little import. Where disposal areas are limited the amounts of sludge are great, ultimate disposal of the solids from sewage treatment may be a problem of some magnitude. Thus preparation and sale of fertilizer or incineration may be the best solution. Economic factors dictate the type of ultimate sludge disposal.

Many persons regard sewage sludge as a soil conditioner or soil builder, rather than a fertilizer in the strictest sense. In some states the legal definition of a fertilizer precludes the possibility of classing sludge as a fertilizer because the chemical constituents are below the legal specifications.

In a few cases, dried sewage sludge has been fortified with nitrates, potash and phosphates but in general there is no economic gain, it is as easy to buy and spread both the sludge and the fertilizer.

Heat dried activated sludge appears to be the best partly because it is free from weed seeds, blends quickly and easily with the soil and has but a very slight odor. Lawns fertilized with sewage sludge have a dark green color and a strong stand of grass.

Transportation of sludge to the consumer presents one of the big problems and is a factor in the economics of the sale of sludge by a sewage treatment works.

Weed-Free Sludge Beds

By L. A. CONN

Tech. Representative, E. I. du Pont de Nemours & Co., Inc., Wilmington, Dela.

WEEDS are sometimes defined as "plants in the wrong place"—and they can find a good many wrong places to get into around a sewage treatment works. They particularly like to deface the clean sand surface of sludge drying beds, when not in use, or tangle fence-rows and retaining walls where a power mower can't reach them. Railroad sidings and gravelled areas are also "fair game" for weeds.

Hand-grubbing and trimming are tedious and disagreeable, and present an increasingly difficult labor problem. Wages alone make this kind of hand-work an expensive luxury, aside from the fact that workmen object to long hours of toil in the hot sun.

Raymond E. Anderson, district chemist-engineer for the North Shore Sanitary District in Illinois, has been grappling with the weed problem ever since he first took over his job in the trim, yellow brick building outside Waukegan, nine years ago. He's watched the workmen invent tools of their own—one that looks like an ice-scraper or lawn-edger; and another that is simply a power saw blade welded to a handle. But Joseph Debevic, acting plant superintendent, says most of those tools "just transplant the weeds." One of the most troublesome is pepper grass, and another is smart weed.

Ed. Note. At the time that the Waukegan experimental work was conducted the product employed was known as CMU Weed Killer. We are advised that the material is now being marketed under the new name—"TELVAR-W."

SIX-INCH swath along fence treated with weed killer eliminates hand clipping

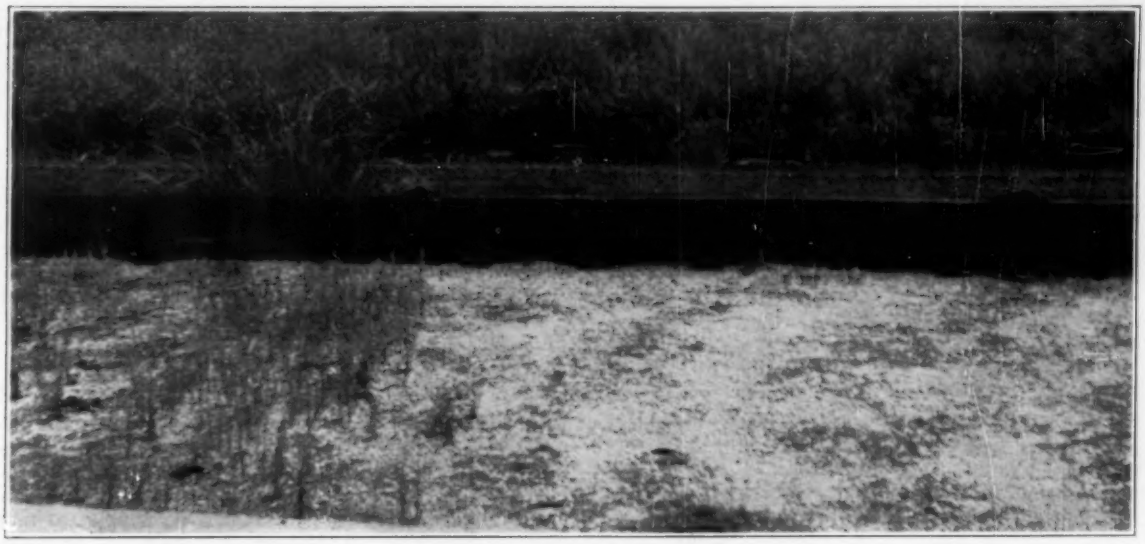
Best Maintained Plant

Long hours of hoeing in the sludge-drying beds have just barely kept the weeds under control in the past—and the job was never finished all summer long. Even under this handicap, in 1951 the Waukegan plant won the Illinois State Health Department award for the best maintained plant in the state. This was a proud achievement for veteran plant superintendent Matt Kirn, now on leave of absence, and for his operators. And in September of 1952, when the State Association visited the plant, "the grounds never looked better" said Joe.

But something new had been added to their maintenance program before that state meeting—a chemical weed killer that cut about 85 per cent of the labor out of weed control during 1952, and was still keeping the sludge-drying beds clean nearly a year after application.

Any chemical used for weed control in the beds has to meet exacting requirements. Anything based on oil might collect so much dust it would

Simple chemical treatment frees labor for more productive duties



UNTREATED and treated areas of sludge bed

Results from application of 2 ounces of "Telvar-w" per 100 sq. ft. in Aug. 1952. Photo taken in June 1953

clog up the beds. Water-soluble compounds might wash right through at the first rain, without lingering long enough to do the job. Chemicals used in large quantities might affect the functions of the bed itself.

What's needed is a long-lasting compound, effective in small quantities, that won't interfere with the normal processes or work programs of the plant.

Ray Anderson thought he saw hope in a clipping about "CMU" Weed Killer* which came across his desk early in 1952. He obtained just two pounds of the material in March, and arranged for test applications in April, before weeds had come up in the drying beds.

The chemical comes as a wettable powder which forms a suspension in water. Selecting four plots, each 216 square feet, Ray tried four different concentrations—one, two, three, and four ounces per gallon per 100 square feet. No weeds came up in any of the plots—while in check areas alongside, the weeds were as plentiful as ever.

In June, another area was sprayed —this time 1,875 square feet. Ten ounces of the chemical in five gallons of water killed weeds that were already three to eight inches high, and the beds stayed clean all summer. This single application of 0.53 oz. of CMU powder* per 100 sq. ft. proved ample.

Trials Successful

With this trial experience, Anderson and Kirn went to John S. Whyte, president of the five-man board of trustees, told their story and invited Mr. Whyte to see for himself.

As a result, the North Shore Sanitary District purchased enough CMU Weed Killer* to treat all the drying beds at the Waukegan plant. A wheelbarrow model power sprayer to apply it was also purchased. One of the laboratory assistants weighed out 66 pounds in 15-ounce portions in paper bags to speed the refill operation, and then at the rate of 15 oz. per 1000 sq. ft., they sprayed a total of 70,000 square feet, or 1.6 acres. They also sprayed some along the fence-lines and retaining walls to kill the weeds and grass so a power-mower could do virtually all the lawn-clipping.

Raymond E. Anderson, chemist-engr., and Joseph Debcvic, acting plant supt., examine weeds from sludge beds of their plant.

A three-gallon hand-sprayer was used in the original test work, but the 10-gallon wheelbarrow model sprayer was used for the larger applications. This sprayer has an agitator, which is essential to keep the powder suspended in the spray tank. A hose delivering water right to the job and the 15 oz. bagged charges of the CMU* materially speeded up the work.

The Waukegan plant is the largest of 11 plants in the North Shore Sanitary District, which runs along Lake Michigan from Highland Park, Illinois, to the Wisconsin state line. Louis K. Ekstrand is superintendent of the plants outside of Waukegan. With the success achieved in Waukegan, the trustees of the Sanitary District feel optimistic about holding their own in maintenance contests from now on. CMU (now known as "Telvar-a") has proved to be the workmen's "best friend"—no more weeding in the hot summer sun. In addition it poses no safety problems, such as toxicity to the users, damage to clothing, nose and skin irritation, or fire hazard.

Maintaining Sewage Metering Devices

A review of simple but essential practices which apply to inferential and gravity flow types of meters

By F. L. SOMMER*
Simplex Valve and Meter Co., Philadelphia, Pa.

THE STRIDES made in recent years in sewage treatment practices have increased the importance of measuring devices, and the sewage meter is now considered essential to proper operation. Thus it follows that an understanding of the meters and their maintenance is also essential.

Meters are used in critical places within the plant for the measurement of raw sewage, clarified sewage, sludge, and air flow. They may be considered desirable, depending upon the installation, for measuring the inflow to the plant, the out-fall from the plant, or measuring flows at various points within the plant. They also may have a definite use in the proportioning of liquids.

Sewage metering devices can be arranged in two broad general classifications, each of which has its own maintenance problems. The first classification includes the types of meters suitable for use where the liquid or gas is flowing through pipes under positive pressure. The second category includes those meters which are used for measurement of flow through open sewers, or of flow through pipes running partially full.

* Mr. Sommer is now associated with Penn Instruments Co.

VENTURI meter with cleaning valves designed to serve as reamers

Inferential Types of Meters

Where liquids must be measured under pressure, the general form of meter used to determine the flow is the inferential type of meter. This is an instrument utilizing a differential pressure-producing device in the line, such as a Venturi tube.

Sewage Venturi tubes usually are provided with a pressure belt at both the main and throat diameters, each belt being equipped with cleaning valves. These are spaced at equal intervals around the circumference of the belt, and are designed to serve as reamers when directed from their retracted position down through the piezometer openings leading from the interior of the tube to the respective pressure chambers. Normally these valves are hand-operated, and it should be the practice of the operator to clean out foreign matter from the piezometers by means of these cleaning valves, approximately one a day. Flushing of the belts should be carried out with a clear water supply.

In order to insure to the greatest possible degree that little or no sediment enters the mercury cylinder of the secondary meter, sediment tanks are installed at some point in the pressure lines connecting the Venturi tube to the instrument cylinder.

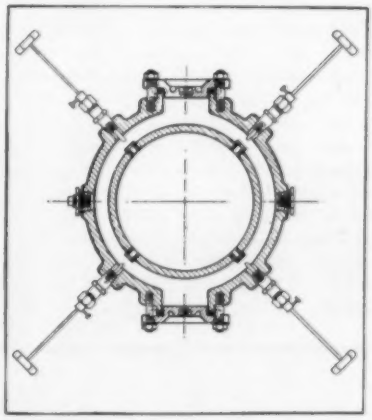
On the upper end of a sediment tank there is attached a flushing device seat, while at the lower end there is a drain cock. The pressure line from the Venturi enters the side of the tank at about one-third the entire length from the bottom, and the outlet to the meter is taken at about the same distance from the top. Thus, any sediment which does find its way into the pressure tank may settle to the bottom and to collect there, rather than proceeding along the remaining length of piping to the meter cylinder,

Water for Flushing Sediment

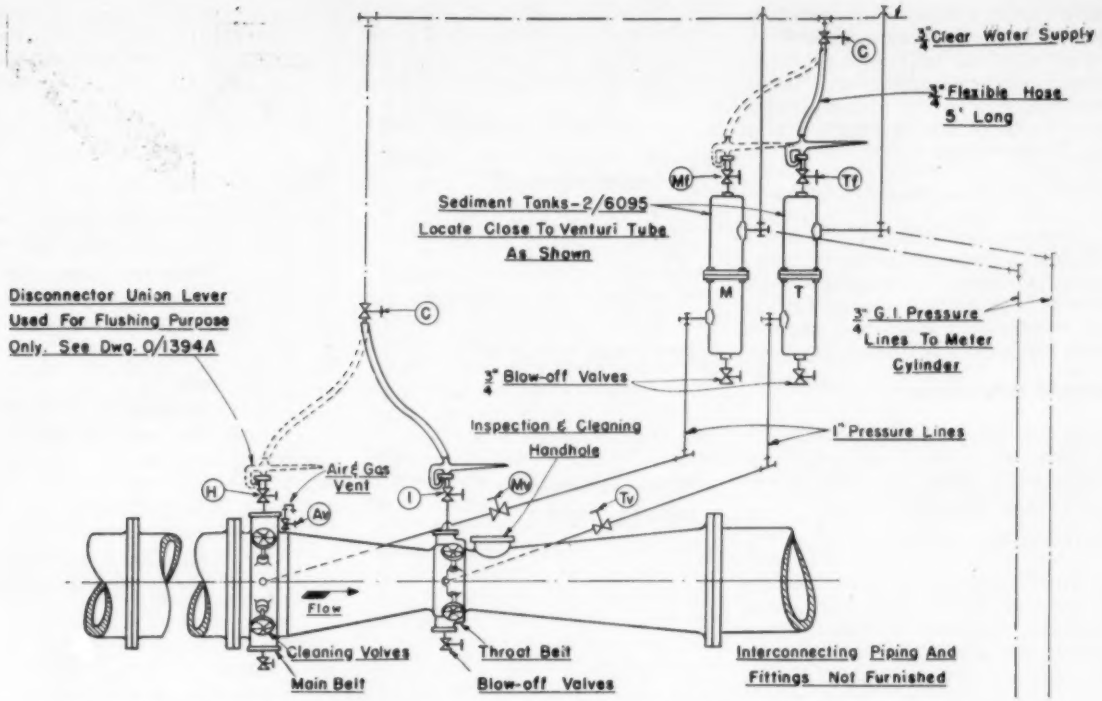
The purpose of the flushing valve seat at the top of the tank is to provide a temporary connection for a clear water flushing supply, so that at frequent intervals the sediment tank may be flushed clean. The tanks usually are placed close enough to the Venturi tube to utilize the same source of water supply as is used for flushing the pressure chambers of the tube.

In those plants having a pressure supply of water not used for drinking purposes, a continuous backpurge of the pressure lines is possible. The liquid generally used is sewage effluent, and normally a pair of special check valves is placed in the purge lines to prevent entrance of occasional solids which may be carried over from the treatment process. Also installed in the pressure lines are small flow indicator regulators, to provide a means of controlling the flow equally to each pressure belt.

Use of the continuous backpurge system does not eliminate entirely the need for maintenance, but does tend to minimize it. Reaming of the piezometer openings is still required occasionally, and the check valves



SECTION through Venturi tube main diameter—at bottom of Fig. 1.


¾" Clear Water Supply
¾" Flexible Hose 5' Long
Sediment Tanks-2/6095
Locate Close To Venturi Tube As Shown
Disconnector Union Lever Used For Flushing Purpose Only. See Dwg. 0/1394A
3" G.I. Pressure Lines To Meter Cylinder
¾" Blow-off Valves
Inspection & Cleaning Handhole
1" Pressure Lines
Air & Gas Vent
Flow
Cleaning Valves
Main Belt
Throat Belt
Blow-off Valves
Interconnecting Piping And Fittings Not Furnished

PIPING CONNECTIONS for a Venturi meter measuring sewage flow. Note the sediment tanks discussed in text.

should be cleaned if the small flow indicators show a stoppage of the water purge.

A better source of water for back-purge purposes is a system similar to that used for pump priming. In this case, clear water is used from a constant head tank fed from a float valve-controlled clear water line. The tank can be located either at a sufficient height to provide a pressure greater than that existing in the line, or a small pump can be used at the outlet to create the pressure required for purging.

All the foregoing deals with the necessity for and the means of keeping the Venturi tube connections clear. This point cannot be stressed too highly. Sewage flow is not easy to measure, and more than half the problem exists in the tendency toward clogging of the lines with solids. If cleaning is performed regularly, many difficulties can be avoided completely.

Periodic Inspection Is Required

In addition, periodic inspection of the meter itself is necessary. No instrument will remain in correct adjustment indefinitely. Every-day handling, such as changing charts, pens, and other routine adjustments, as well as routine meter operation, eventually result in the need for rechecking. Therefore, the establishment of a regular inspection procedure is definitely recommended. The interval may be six months to a year.

Unusual occurrences such as complete shut-down, long idle periods, or more particularly, complete drainage of the system, require special attention. After such occurrences, the meter should be thoroughly checked and adjusted.

Recommended Checking Procedures For Inferential Meters

A recommended procedure for checking meters includes correction or elimination of conditions such as the following:

Sediment in Meter Cylinder

Remove the cylinder head and the float. The entire contents of the cylinder, including mercury, may be removed by opening the mercury drain plug. Flush the cylinder thoroughly with clear water until the sediment is cleaned out. Weigh the mercury and replace the correct amount as specified by the manufacturer.

Leaks in Pressure Lines

In many installations the pressure lines are buried, and unseen leaks may develop. Tests can be made, however, by the following method: With the meter operating at a specific rate, close the throat valve at the Venturi tube. If the meter pointer remains stationary, there is no leakage in the throat pressure line.

If the pointer moves to a higher value, the line leaks. Close the equalizing valve to stop further rise, and repair the throat pressure line. If the pointer drops backward towards zero, it indicates leakage probably through the equalizing valve.

The same test is then applied to the main connection after the throat valve has been re-opened. In this case, however, if the pointer moves toward zero, the main piping leaks, and should be repaired or replaced.

Obstructions in Pressure Lines

Flush the pressure lines to remove sediment. It may be necessary to replace them if in an extreme case of the blockage cannot be flushed out.

Air Trapped in Cylinder

In normal operation, air will never accumulate under the float but, after emptying of the line or pressure piping, absence of air may be assured by the following procedure:

Close the valves at the main and throat connections to the meter, and open the equalizing valve. This allows the mercury float to lower to zero. On

meters using a square root-extracting float, remove the zero stop cover to reveal the float air vent screw, and release any air accumulation below the float. Air in the cylinder above the float is released by other vents in the cylinder cover.

Air Trapped in Pressure Lines

Vent air at all blow-off points, but do this cautiously to avoid an unexpected shower. The lines, of course, should be properly graded so that no air pockets exist which will interfere with free waterway through the pipes.

Related Maintenance

In addition to the previously described conditions which will cause meter inoperation, four other points need occasional checking.

The Packing Gland

The stuffing box, as packed by the factory, should not leak under normal operating pressure. If leaking does occur, the stuffing box nut may be tightened, *but not too much so,* since excessive friction and lag will result.

To add packing, shut off the main and throat valves and release the operating pressure. Remove the knurled packing nut and pull the brass bushing from the gland. Add the packing and replace bushing and packing gland. When the packing becomes hardened after long usage, it should be completely replaced, using the special packing furnished by the manufacturer.

Oiling

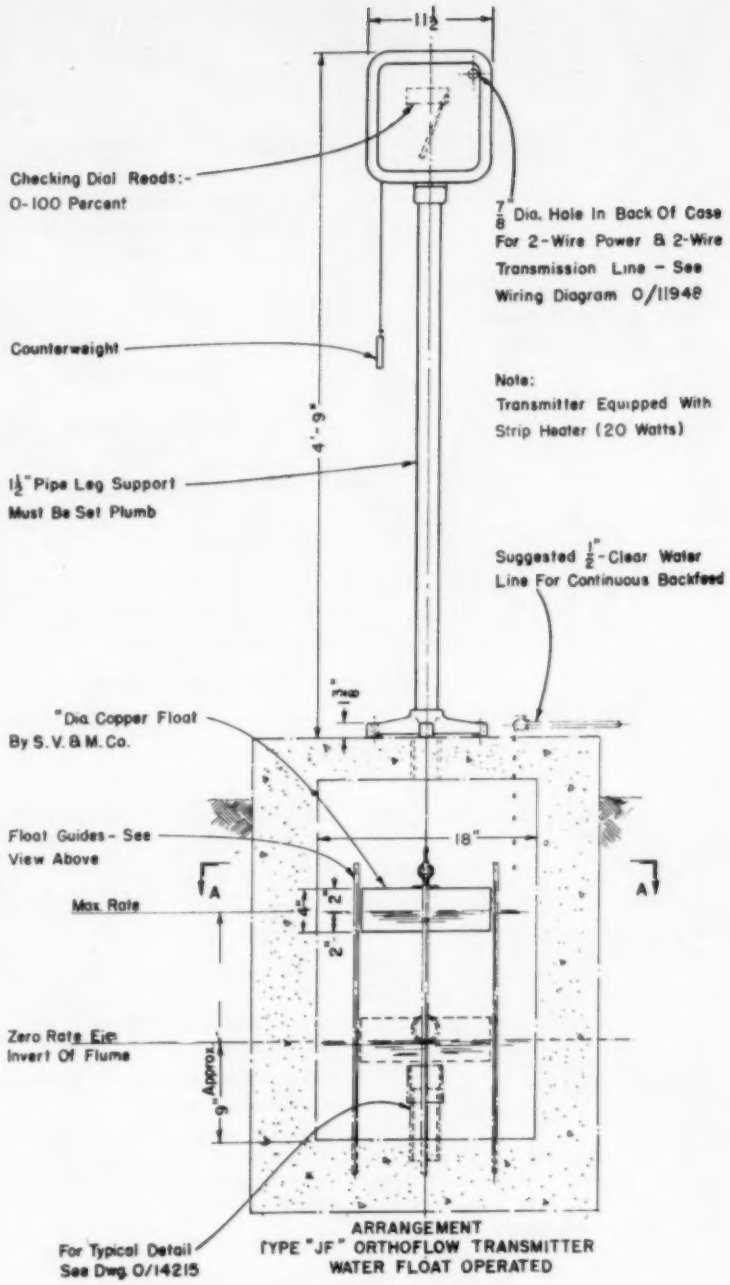
Chart clocks and totalizer drive gears may be oiled lightly from time to time, but avoid oiling other totalizer mechanisms. They may collect dirt, which will interfere with correct operation.

Calibration

The accuracy of the meter depends upon the dial pointer and totalizer adjustment. Most meters are furnished equipped with a water manometer test outfit for setting and checking purposes. The manufacturer's instructions should be followed in carrying out the checking procedure with a manometer.

Chart Pens

Keep chart pens clean to insure a free flow of ink. Use the ink and charts recommended by the manufacturer, to insure that charts provide neat and valuable permanent records.



DETAILS of stilling chamber and float-operated transmitting device.

Gravity Flow Meters

The second classification of meters includes the single head meters which measure gravity flows. Many primary devices are used, such as flumes and weirs of various forms. All these devices depend upon a standard head-quantity relationship, so that at any measured head or level, the flow can readily be determined by reference to a table or curve of graphic form.

In order to maintain continuous metering, a cam is carefully machined, with the head quantity curve embodied in it. For any given rise of a float responsive to the primary level, the meter mechanism is moved by the cam an amount equivalent to the flow value.

The cam may be located within a transmitter if the primary device is

remotely located from the registering point, or may be in the register itself when the float well is directly below the meter.

Recommended Checking Procedures For Gravity Flow Meters

From the standpoint of maintenance, the greatest potential difficulty in operating gravity flow meters is the single transmission pipe from the primary device to the float well. It must be kept clear of solids so that head changes can ge reflected quickly by the float.

A constant dribble of clear water into the float well is the best means of preventing clogging of the line. Keeping the float well filled with clean water (to the level in the primary device) creates a very slight backflow toward the weir or flume. This, of course, tends to keep the fluid being measured out of the piping and the well. It is still necessary, however, to flush the connections occasionally with a pressure purge.

To facilitate cleaning, all changes in the piping should be fitted with plugged tees rather than elbows, to allow rodding if the water purge alone does not suffice for cleaning purposes.

In addition to the piping, the float and float well also must be clean and free from solids which would interfere with free movement of the float. A blow-off point should be provided at the bottom of the well to facilitate cleaning at this location.

It is not always possible to provide the clean water dribble into the float well; in these cases, special attention must be given. Frequent cleaning is generally required, unless the fluid being measured is clear final effluent. A manual type force pump often is used for purging of this type.

Minor Adjustments of Meters

Finally, in addition to keeping a free flow of liquid between the primary and the float well, the metering instrument must be kept in calibration by following the manufacturer's recommended procedure. The recording pen must be kept clean to insure free flow of ink, and certain parts must be oiled.

Most standard meters are so simple in construction that any operator should readily be able to assimilate its details and operating characteristics, and to make minor adjustments by reference to the instruction booklets provided.

When testing or repairs of a more complicated apparatus are needed, consult the manufacturer's field engineers. Unquestionably, this is proper practice with regard to equipment such as proportionate controls, summation units, and the various forms of electrical transmission.

With standard equipment, however, it is possible for the operator to make his own adjustments and simple repairs without outside assistance. If each operator will familiarize himself with the salient points of his metering equipment, he can learn to make minor adjustments easily, and thus can save many hours or days that would be required in waiting for field engineers to reach the plant.

Service engineers always are happy to supply information and to give the benefit of their experience and knowledge. By close contact with the serviceman on the job, the operator can learn not only the principles involved in the construction of metering equipment, but the short-cuts of technique in repairing and adjusting it. This information makes possible more efficient meter operation. An example of knowledge which can be gained by working with a service engineer installing or repairing the equipment, is that of the points in each type of metering apparatus which require special attention.

Conclusion

The condition of plant equipment is a good index of plant efficiency. There is no reason why any essential equipment should be allowed to remain idle or in poor operating condition. Though there may be extreme cases where this is temporarily necessary, the slight extra expenditure of time and money required cannot balance the loss of efficiency and of vital operating records that result from faulty meter operation.

It is the purpose of this discussion to bring to the sewage treatment plant operator's attention a few of the remedies applied by manufacturers' service engineers. Although the need for these representatives will, no doubt, never be eliminated, it is believed that plant operators can adopt many of their techniques, and can improve maintenance programs on their own initiative. Operators who do so thus place themselves in a better poistion to provide uninterrupted operation of a sewage treatment plant.

Syndets In Municipal Sewage

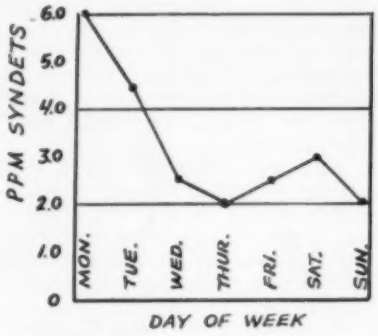
By DON K. CROFT and SAMUEL D. FAUST

Respectively, Proj. Engr., Baker-Wibberly, Inc. and Chem. W. A. Taylor Co., Baltimore, Md.

A SYMPOSIUM held under the auspices of the Amer. Chem. Soc. Division of Water, Sewage and Sanitation Chemistry reviewed and evaluated reports of the detergent effect on sewage and water treatment.[4] The symposium concluded that there are wide variations of opinion as to the practical effect of syndets in sewage, but whatever problems do exist, certainly are not of a temporary nature.

Another symposium on the subject was held by the Fed. Sew. & Ind. Was. Assns. at its 25th meeting in New York City in Oct. 1952.[5] Water treatment plants may soon be affected by detergents in raw water. Culp and Stoltenberg[6] presented a paper describing the difficulties encountered in treating water at Osawatomie, Kans. Surfactant use is on the increase and will no doubt continue to increase. England has contributed largely to our present day knowledge of the subject. Hurley's statement[5] that little thought is needed to make clear the fact that the investigation of the whole problem of treating detergents at the sewage works would need an immense amount of research work. The same is true of sewage treatment plants here in America.

In the ACS symposium, no apparent mention was made of sewage analyses that would shed any light as to the actual detergent content. Data, collected on the problem, were



VARIATION of syndets during a week

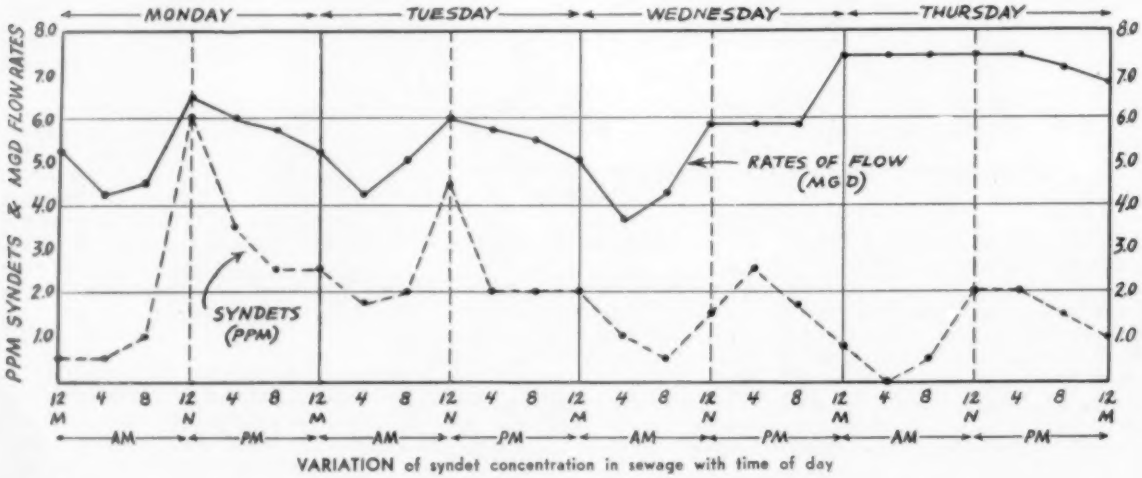
obtained by adding known amounts of the compounds to influents and effluents. Keefer[1] was one of the first investigators to provide information on concentration and removal of this new constituent in sewage stating that, "one of the reasons for the lack of information on the subject of syndets in sewage is, that many of the laboratories at sewage treatment plants are not equipped to determine the detergent content of sewage." This observation led to an investigation for a simple, reasonably accurate colorimetric method for the determination of these compounds, one that a sewage plant operator can manipulate.[3]

Present Research

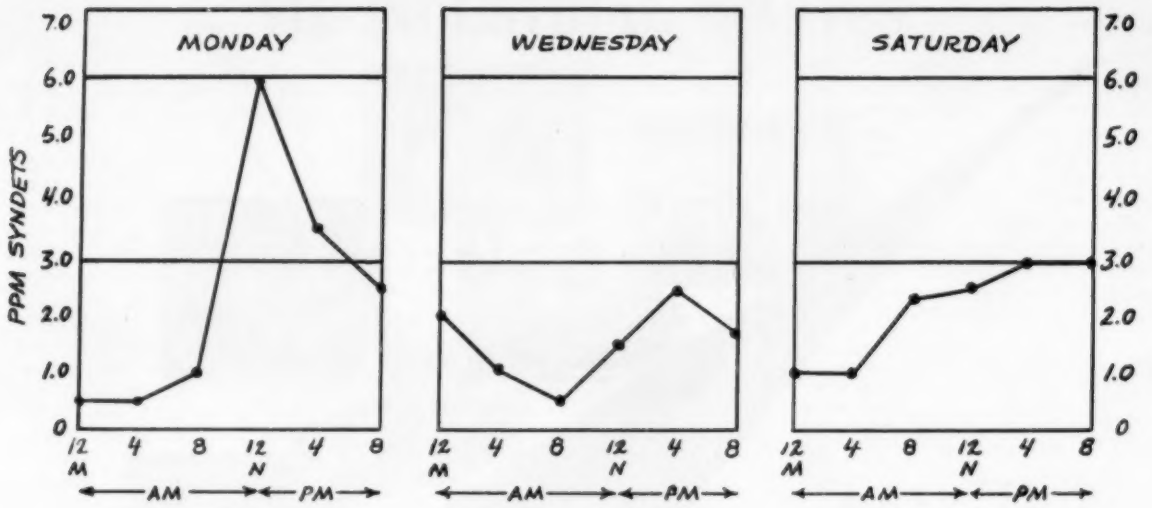
In cooperation with W. A. Taylor & Co., and using the method reported[3], personnel at Hagerstown's Sewage Disposal Plant conducted the research reported here. Extending over a seven-day period from December 8, 1952 to December 14, 1952, samples of raw and treated sewage were collected every four hours. The hour and rate of flow were recorded simultaneously. The object of this work was to correlate and evaluate information relative to the detergent content day by day, hour to hour, during any given day and rate of flow.

In order to appreciate this information, it is necessary to use the graph method in recording the data. Figure 1 shows the detergent content in parts per million plotted against days of the week, while Fig. 2 plots the detergent content in parts per million against sampling hours on three different days. Figure 3 shows a graph of rate of flow and concentration of syndets plotted against time for a four-day running period.

In Fig. 1 the maximum "syndet" concentration for each day is shown. The high for the week was 6 ppm which passed through the plant on Monday. This is attributed to "wash day." The low concentration occurred on both Thursday and Sunday. After Thursday, the concentration rose on Friday and Saturday (3.0 ppm) then dropped again on Sunday. This type of graph can provide helpful information for the plant operator. If neces-



VARIATION of syndet concentration in sewage with time of day



VARIATION of flow and syndet concentration with time of day

sary, special treatment can be applied to combat any damaging effect on sewage digestion processes.

Figure 2 shows the study made every four hours throughout the day on Mon., Wed. and Sat. On Monday when the highest concentration (6.0 ppm) was observed, the "syndet" concentration remained below 1.0 ppm from midnight to 8 a.m. From 8 a.m. to noon a big rise in the curve is noticed with the reading of 6 ppm at noon, as the high for the day. Wednesday's curve decreased from midnight to 8 a.m., then rose to a 2.5 ppm peak late in the afternoon. Saturday deviated from the patterns of other days, beginning low at midnight and 4 a.m. and rising through the day to a peak of 3.0 ppm at 4 and 8 p.m. Generally the highest concentrations were found from noon to 4 p.m. during any given day.

In Fig. 3, the syndet concentration and rate of flow are both plotted against time for four days. The upper curve is the rate of flow in million gallons daily, and the lower curve is the detergent concentration in ppm. The two curves follow a general rising and falling at the same time. The flow data, however, on Wednesday through Sunday were complicated by rainfall. For that reason, it would be unwise to designate a certain flow and attach a definite syndet concentration to it.

Removals

Data were also collected on syndet concentration in the effluent from the primary tanks and from the final effluent. These data are shown in Tables 1A and 1B. Data in Table 1A were collected across the plant at the same hour. Some retention or removal of the detergent by the solids is apparent, but the data in Table 1A actually represents three different samples examined. The samples collected for Table 1B allowed for detention time of the treatment processes and represent more accurate results. These data also show retention or removal of the detergent.

In order to determine whether or not any detergent is actually being removed by the solids, a test was made on an effluent from an aeration unit. As sampled, a reading of 3.0 ppm "syndet" was recorded. The solids were allowed to settle. Examination of the supernatant liquid gave a reading of 2.00 ppm. Again there is evidence of detergent removal.

The Future

Since the domestic and industrial use of the surface active compound is increasing each year, it may be wise for the sewage plant operator to consider all possible situations. The biggest problem lies in the excessive use of the detergent by the public.

Another possible variable, not taken into consideration, is the season of the year. We can safely assume in the spring, summer, and fall months there will be an increase in consumption of "syndets." Larger laundry loads, and more car washings are among the contributing factors.

The writers hope that this paper has contributed in some small way to knowledge of this increasing treatment problem. Hagerstown's data are assumed to be typical of other cities and communities.

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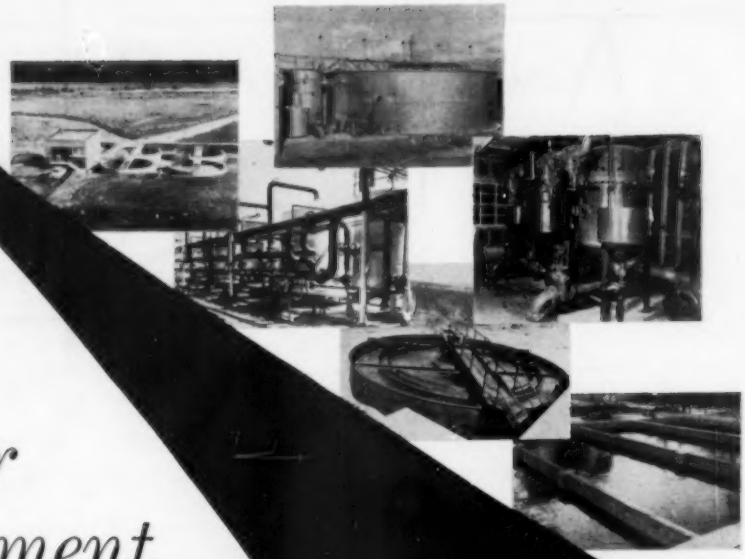
Table 1

REMOVAL OF SYNDETS IN SEWAGE TREATED

A—SAMPLES COLLECTED AT SAME HOUR

Concentration of Syndets in ppm.

Day	Raw Sewage	Settling Tank Effluent	Trickling Filter Effluent
Friday noon	2.0	1.0	0.5
Monday noon (12-2-52)	5.5	3.0	1.0
Mondal a. m. (12-8-52)	1.0	0.5	1.0
Tuesday noon	4.5	1.75	1.0
Wednesday p. m.	2.5	2.0	1.5
Thursday p. m.	1.5	1.0	1.0
Friday Midnight	1.0	1.5	1.0
Sunday a. m.	0.5	0.25	0.0
B—Samples Collected Allowing for Detention Time			
Tuesday	2.75	2.5	1.5
Wednesday	3.0	2.5	2.0



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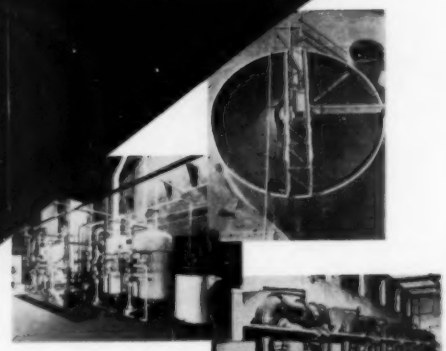

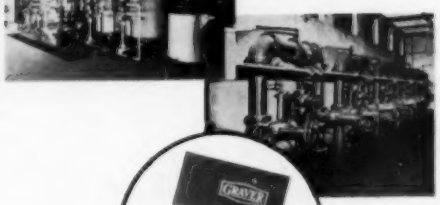

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VII. INDUSTRIAL WASTES

THE PROBLEMS of industrial wastes are many, varied, and extreme. According to the U. S. PHS there are more than 10,500 industries which discharge liquid wastes. Of these, approximately one-fourth treat their wastes at least in some degree; another fourth discharge untreated wastes equivalent to a population of perhaps 60 million persons. Data are not available on the remaining 50 per cent but probably half produce organic wastes and the remainder produce inorganic or mixed wastes.

With this tremendous waste load reaching the rivers, lakes and oceans, it is easily understandable that the industrial waste problem represents a large economic loss; a loss in salvageable material, in corrosion, in increased costs of water purification and public health measures, and losses in property values and recreational areas. No one has calculated the extent of the economic loss but it has been estimated to amount to several billion dollars annually.

Quantities of Waste

Some idea of the extent of the waste problem can be obtained from an understanding of the volumes of water used for industrial production. Table 1 indicates water requirements for some typical industries.

Character of Wastes

Industrial wastes are often classified according to type of industry. The general classifications include: Chemicals, Fermentation, Food Processing, Metal Processing, Mining, Petroleum, Pulp and Paper, Textile, and Miscellaneous. In these nine general classifications, there are approximately seventy different industry wastes.

From the considerations of treatment, industrial wastes are often classified as inorganic, organic, and mixed. In general, inorganic wastes require treatment involving chemical and mechanical (physical) processes; organic wastes require treatment by biological processes and possibly also chemical and mechanical processes. Mixed wastes will require treatment involving physical separations, chemical treatment and biological treatment.

Treatment Processes

One of the most effective "waste treatment processes" is by product recovery and although this method of treatment may not show a profit, sale of the byproduct may reduce the cost of over-all treatment. Other operations within the producing plant may also reduce the waste load leaving the plant without unduly increasing the costs of production. These operations include change of processes, separation of cooling water, recycling wastes, and evaporation of highly concentrated wastes. Where these operations will not reduce the waste load sufficiently to make it acceptable to a municipal sewer system or to a receiving body of water, then some form of treatment will be necessary.

The extent of treatment and the processes involved depends on volume and concentration of waste, its toxic content and the dilution available in the receiving water. For each plant, the solution selected should produce the desired result at the lowest possible net cost.

Among the unit treatment processes which may be applied to wastes are those listed immediately below, but not every one of these processes is applicable to every type of waste:

Aerobic biological oxidation
Anaerobic digestion
Chemical Coagulation
Chemical Oxidation
Chlorination
Deionization
Dewatering
Drying
Filtration
Flocculation
Flotation
Incineration
Ion Exchange
Lagooning
Neutralization
Screening
Sedimentation
Spray Irrigation
Vacuum Filtration

Industrial Waste Surveys

Where industrial wastes are discharged directly to streams and abatement of pollution is desirable, a survey of the problem is the first step. Governmental bureaus are usually interested in such surveys and may participate. Within a community the survey may be performed by municipal engineering services or consulting engineers. In any industrial waste survey, no matter by whom conducted, the purpose is not to persecute industry but to establish the extent of the problem and the solution.

The first step in an industrial waste survey is to obtain adequate publicity to the general public and the industries emphasizing that the cooperation and aid of industry is the paramount consideration. The second step is to list and classify all industries within the area surveyed. From this classification, industries having no liquid wastes (except sanitary) may be eliminated. Other classes should be listed in order of known relative strength or importance. The third step is to request each industry by letter to appear at a conference with representatives of the organization making the survey. The fourth step is to conduct an actual investigation of the sewers and wastes within a plant, the plant processes, etc. This part of the survey involves not only questions of plant management but also measurement, sampling and analyses of the actual wastes. From this information the solution to the problem usually can be devised.

TABLE I
Industrial Water Requirements

Type of Industry	Unit of Production	Gal of Water Used per Unit
Chemical Industries		
Starch	ton	333
Alcohol	ton of grain	20,000
Amm. Sulfate	ton	200,000
Food Processing		
Beet Sugar	ton	25,000
Canning	100 cases	200 to 25,000
Meat	live units	16,000 to 55,000
Milk Products	100 lb	200 to 250
Textiles		
Cotton	100 lb	1,000 to 3,000
Linen	100 lb	10,000
Rayon	100 lb	8,000 to 10,000
Wool Scouring	100 lb	2,000 to 12,000
Petroleum		
Oil Refinery	100 bbl crude	77,000

Industrial Waste Trailer

by ARTHUR D. CASTER

Principal Engineer for Sewage Disposal, Division of Engineering, Dept. of Public Works, City of Cincinnati, Ohio.

ONE OF the essential activities included in the Greater Cincinnati Metropolitan Sewage Disposal Program is the gaging, sampling, and analysis of trade wastes discharged by some 700 industries into the sewer system and which eventually reach the sewage treatment works. Such an operation is necessary to establish equitable surcharge rates based on waste strengths and to protect the sewer system and treatment works from toxic and otherwise undesirable waste constituents.

It is imperative, therefore, that the field operation of flow measurement, sampling, compositing and pH determination, as well as the laboratory analysis, be carried out with the highest possible degree of precision and accuracy. Laboratory precision is relatively easily attained, but accuracy in the field presents a variety of problems. To combat these problems, engineers of the Sewage Disposal Section have developed and designed several items of special field equipment which greatly increase the accuracy of field determinations.

General Construction

Perhaps the most versatile and useful of these devices is the industrial waste gaging trailer designed entirely by the sewage disposal engineering staff and built by maintenance personnel of the Little Miami sewage works. It is fitted with a pneumatic flow recorder, an electrically operated pH meter, and a pH recorder. A self-contained gasoline engine generator and electrically driven air compressor enable use of the trailer away from an external power supply. The equipment is all fully automatic and the trailer could be left unattended if necessary, although it is not general practice to do so.

Figure 1 shows the general construction of the trailer.

The basic trailer is an Army surplus, two-wheeled, 1-ton unit with the body removed and replaced with a flat plywood bed. It is equipped with a standard ball-socket hitch, a hand brake and turn signals. Three jack-screws were installed, one on each rear corner and one on the front tongue, to serve as adjustable leg supports to enable the trailer to stand by itself. Red signal lamps on each corner are for purposes of identification at night.

Structural steel angles were welded together to form a rigid frame for the body box. The side and end panels are of marine plywood, hinged at the top for opening and exposing the instruments and other equipment. A generous amount of space is provided for tools and other items of equipment.

Flow Recorder and Power Plant

The pneumatic flow recording apparatus consists of a transmitter, a receiver, and accessories. The transmitter is of the air-bellows type providing an output air pressure directly proportional to the level over the crest of a 90° V-Notch weir. It is actuated by a bubbler pipe system which converts the head on the weir to an increased pressure of from 3 to 15 psi.

The receiver operates with a corrosion resistant metal bellows and incorporates both a totalizer and a recorder. The totalizer is driven by a 110-volt ac motor; the recording chart is rotated by a synchronous electric clock mechanism.

The air pressure for the instrument is supplied by a 20-cfm electrically driven air compressor. The compressor is fully automatic and is furnished with a storage tank of 5-gallon capacity, intake air filters, and overload safety mechanisms.

Power for the compressor motor as well as all other electrical devices on the trailer is supplied by a gasoline-driven, 115-volt, 60-cycle, single-phase generator with a 100-watt power output. However, if an outside source of electricity is available, it is used. Figure 2 shows the power plant and generator installation.

Fig. 1—INDUSTRIAL waste gaging trailer unit is arranged for maximum convenience.

Trailer Equipment List

pH Meter and Accessories—Beckman Instruments, Inc.

pH Recorder—Minneapolis-Honeywell Regulator Company

Pneumatic Semi-Portable Recording Flow Meter and Accessories—Builders-Providence, Inc.

Air Compressor—Saylor-Beall, 1.63-CFH rating

Generator—Empire, 1000 w., 115 v., 60 cy., single-phase

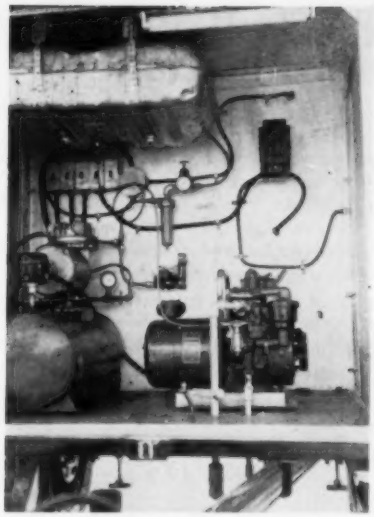


Fig. 2—GENERATOR and compressor bay.

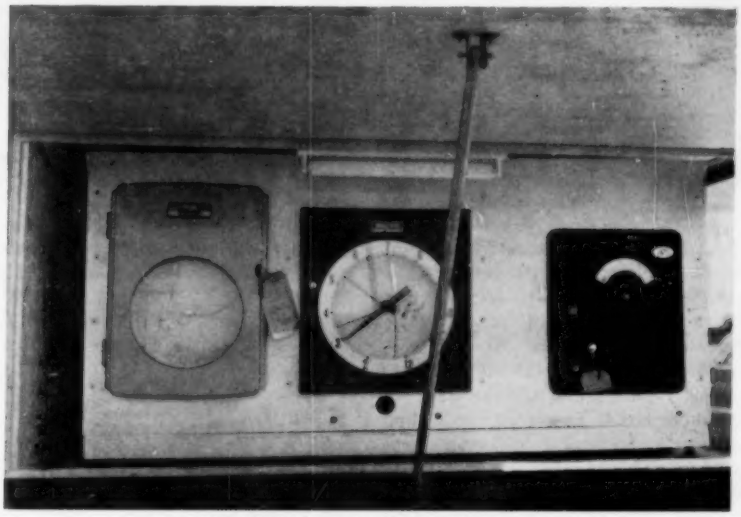


Fig. 3—INSTRUMENT panel includes pH and flow recorders.

pH Meter and Recorder

The pH apparatus includes a potentiometer, a recorder, electrodes and accessories. The recorder chart is rotated by a motor drive operating at 115 volts. The electrodes are designed for direct installation in pipe lines or open channels and are protected from damage by floating solids. The potentiometer indicator and the recorder are mounted on the instrument panel with the flow recorder. The instrument panel is shown in Figure 3.

All of the instruments and their appurtenances are mounted on springs for cushioning against shock encountered while moving the trailer from place to place. The air tube for the flow meter and the leads on the pH electrodes are of sufficient length that the trailer may be situated a maximum of 50 feet away from the gaging and sampling point.

The compactness and self-sufficiency of the trailer make it extremely useful to the Sewage Disposal Section. It has been in service only a few months, but has already seen considerable use, mostly in conjunction with sewer damage investigations. The benefits derived from the use of the trailer are expected in a short time to more than compensate for the expense involved in its design and construction.

The following is an itemized account of the costs involved in the design and construction of the trailer:

Trailer (Army surplus)	$ 99
Flow recorder (incl. compressor and accessories)	1,300
pH meter and recorder (including accessories)	1,100
Generator	245
Materials of construction	390
Design	684
Construction labor	710
Total	$4,528

★

Simple Hydrogen Sulphide Determination

by GEORGE MARTIN

Supt., Metropolitan Sewer Dist.,Green Bay, Wis.

IN MAKING routine determinations of hydrogen sulphide in sewage, sewage gas, and polluted waters it was found that the procedure as described in Standard Methods was not satisfactory, due to the fact that polluted waters and sewage have an iodine demand. Therefore, a modified or special method of procedure was adopted. This special method is based upon the known fact that filter paper treated with a lead acetate solution will darken when placed in contact with hydrogen sulphide. It was found that by making a set of standards, with which any sample might be compared, consistent and fairly accurate results could be obtained.

The Apparatus

The apparatus necessary for making these determinations consists of a standard 500 ml. filtering flask, on the inside of which is placed an air diffuser made of a perforated aluminum tube connected to the flask's side tube by means of a rubber hose. On the outside of the side tube there is attached the rubber air intake hose. The lead acetate paper is held in place on the top of the suction flask between a rubber ring, "A," which is a standard Gooch crucible holder for an ordinary two-inch funnel, and a standard Gooch crucible holder, "B," as is ordinarily used with a filter flask. "A" and "B" are held together by a utility clamp fastened to a ring stand. The rubber hose which is attached to the glass tubing of "B" is connected to a suction device.

The Procedure

In making a determination with this apparatus the sample to be tested is delivered into the flask directly from a pipette through the aeration tube. Air is then drawn through the liquid for two minutes and by so doing the hydrogen sulphide passes on up through the lead acetate paper, discoloring it. The amount of hydrogen sulphite is determined by comparing the colored lead acetate paper with the standards and converting the results into the desired units.

In order to operate this apparatus satisfactorily it is necessary that there be at least 100 ml. of liquid in the flask. Thus, if the sample being tested is high in hydrogen sulphide, it becomes necessary to dilute it with hydrogen sulphide free water. If it is desired to have the final results in ppm., this figure is arrived at by multiplying the color comparison in mg. by 1000 (mg. per liter = ppm.) and dividing by the ml. of sample used.

Example: Sample = 10 ml.

Water added to flask ahead of sample = 90 ml.

Color comparison = 0.05

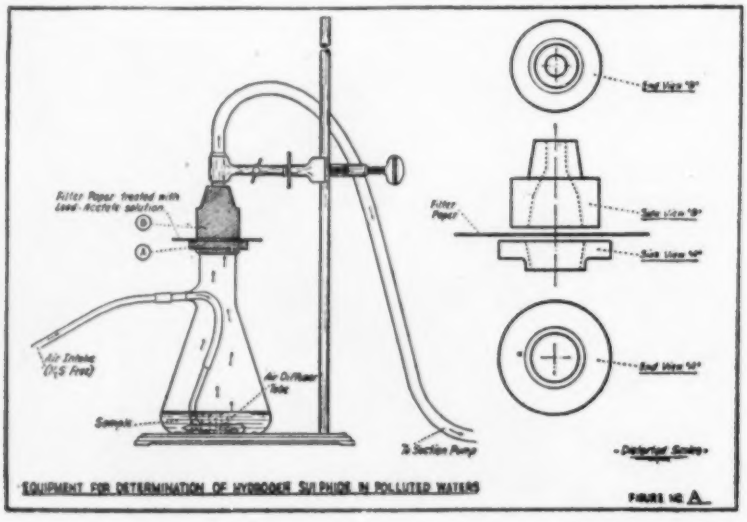
$$\text{Ppm.} = \frac{0.05 \times 1000}{10} = 5 \text{ ppm.}$$

Gas may be tested by hydrogen sulphide content by passing a known volume through the above described apparatus.

Test Papers and Standards

The lead acetate paper is prepared by soaking filter paper in a 10 per cent solution of lead acetate and drying in an oven until approximately 10 to 15 per cent of the moisture remains in the paper. The paper must then be kept in an air-tight container.

Standards are made from a solution of hydrogen sulphide prepared by generating hydrogen sulphide in distilled water from iron sulphide by the addition of dilute sulfuric acid, the solution being standardized by iodine titration.



EQUIPMENT FOR DETERMINATION OF HYDROGEN SULPHIDE IN POLLUTED WATERS

FIGURE NO. A

VIII. DESIGN AND CONSTRUCTION

MANAGEMENT, operation and maintenance of water and sewage works occupy most of the attention of persons engaged in the supervision and operation of water utilities or sewage facilities. Two other responsibilities often are assigned to such personnel are: Design and Construction supervision.

In many cases, consulting engineers are called in to do the design work and supervise construction but the water or sewage manager, superintendent or engineer frequently handles smaller jobs himself or at least must be familiar with the problems involved and the extent and progress of the work. The subject of design factors is best understood if he is familiar with the subject of water supply and sewage treatment. Construction, on the other hand, requires a knowledge of equipment, machines and techniques not used in plant operation.

Trenching

It does not matter whether it is a water utility or sewage works, the laying of water mains or sewer lines involves the same problems and equipment.

One of the common jobs in laying lines is that of breaking the pavement. Power-operated hand tools are necessary to this work. These may include hand held tools operated by compressed air, electricity, or self contained gasoline engines. These tools may be fitted for a wide variety of jobs from a chisel blade for cutting asphalt to a moil point for breaking concrete or foundation, or a narrow gad for removing brick or stone blocks.

Portable air compressors of 60 to 500 cfm capacity may be used for operating air driven tools. The number of water and sewage works which have their own air compressors continues to grow as the need for and versatility of these machines becomes apparent to superintendents of water and sewage works.

Next job after breaking pavement is that of excavating trenches. Trenching machines will save both time and money over pick and shovel excavation. There are many types of trenching machines available and their use depends on width and depth of trench, type of soil, presence of other underground facilities and other factors. The most common types of excavation equipment used includes trenchers, back hoes, clam shells, drag scrapers and power shovels.

Trenchers or ditchers may be of two kinds; one carries ten or more digging brickets on a large wheel, the other on a boom. The latter is sometimes termed a ladder-type digger. Trenchers are used for ditches up to 4 ft wide, clam shells and power shovels will cut any size trench, the former are used for deep trenches.

In digging trenches, provision must be made to prevent caveins in the trench walls. This usually is done with sheet piling properly braced. Backfilling must be done after the water pipe or sewer line is installed. For this purpose either a bulldozer to push the dirt into the trench, or a drag scraper may be used. When the trench is backfilled, the soil must be settled either by puddling or by tamping. Pneumatic tampers can be operated by hand, or mechanical rammers, gasoline driven, may be used.

Tunnelling is a necessity in many locations. House connections can often be laid in this way, using either boring or pushing machines. Holes of 2 in., 8 in. or up to 36 in. in diameter can be bored by special equipment. Pipe up to 4 in. in diameter can be pushed without tunnelling in good soil for distances of 50 to 150 ft There are several makes of pipe pushers on the market using hydraulic power, hand or gasoline motor.

For large tunnels the Armco Co. furnishes liner plates for tunnels ranging from 4 to 33 ft in diameter. The construction of large tunnels is usually not in the domain of the operating manager but laying water mains and sewers of nominal size is a problem he may face often.

Dewatering

When ground water interferes in the laying of water mains or sewers, it is necessary to remove it by pumping. Trench water is removed by diaphragm or centrifugal pumps, operated by gasoline or electric motor. Hand operated diaphragm pumps are also used where the quantity of water is not great. Centrifugal pumps must be self-priming and non-clogging. There are many dewatering pumps on the market.

Another method of reducing water in trenches or other excavations is the well point system. Well points are driven to a depth of 5 ft or more below the trench depth and the points are usually 2 in. in diameter and are spaced from 3 to 6 ft apart, some 2 to 5 ft outside the trench along one side. These well points are connected to a single header connected to the suction of a pump. The depth, spacing, number of well points, etc. depends on the depth of trench, length of trench open and amount of water. Excavations for building structures can be dewatered by the same system.

Installing Mains & Sewers

The techniques of installing water mains is a matter requiring considerable skill, from the preparation of the bed to the lowering of the swabbed pipe and the jointing either with lead or sulfur joint compounds. The techniques of installing sewer pipe, particularly tile, does not require quite so much care in installation. On the other hand, more care and attention given to laying and jointing pipe the better the sewer, the less likely that it will leak or allow infiltration and the less the possibility of the entrance of tree roots.

Concrete Construction

Concrete is generally used for building foundations, manholes and sewers. Modern construction practices generally use concrete mixed at a central plant or truck mixer. Forms for manholes, tanks, sewers, etc. can be obtained from several manufacturers.

Prefab Construction

In place of concrete structures, prefabricated steel underground structures are used particularly for underground pumping stations on sewer systems. Many advantages are claimed for this type of construction.

Materials of Construction

Water lines require pipe; sometimes cast iron, sometimes asbestos cement, sometimes steel. In addition, all pipe lines use valves (cone, butterfly, gate, or plug) and fire hydrants. Sewer lines use sluice gates.

Any list of materials of construction must include corrosion resistant materials, such as ceramics, alloys, etc.; other materials include protective coatings, points, lacquers, plastics, rubber base paints, etc.

In the building of water and sewage facilities there are few materials of construction or equipment necessary to contracting that are not used. The construction of water and sewage works makes up a significant part of the total construction value each year.

Cleveland "Baby Digger" averages 3,500' of 22" x 36" water line trench daily, digging in clay and rock

R. L. Eatherly of Carthage, Tenn. got good daily trench production with his Model 95 Cleveland "Baby Digger" on this water line contract in the Belshire Subdivision in Nashville. Averaging 3,500 feet per day, the Cleveland cut 4 miles of trench, 22 inches wide by 36 inches deep in curving roadways on a subsoil composed of clay with fairly heavy rock content. The Cleveland's completely unobstructed operator visibility and the convenient grouping and location of its controls for easy accurate digging were definite advantages in cutting the curved trench. Just another example of the outstanding ability of Cleveland Trenchers to *dig more trench . . . in more places . . . at less cost.*

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CLEVELAND

Trenching Practice

by RICHARD BENNETT, C.E.
City Engineer, Phoenix, Ariz.

PART I—EARTH TRENCHING

A TRENCH is an excavation having vertical sides and considerable depth in comparison to its width. For purposes of this article it will be considered as being less than 6 ft. in width and not more than 30 ft. in depth, which permits excavation by modern trenching machinery.

Trenches are dug for all kinds of pipe lines, including water, sewer, gas, oil, drains, conduits, etc. The large amounts of trench excavation made necessary by the installation of pipe lines for the various uses has led to many improvements in this practice.

Many of the early forms of trenching machinery such as the traveling derrick, the trestle cable excavator, the tower cableway, the trestle-track excavator, etc., have all given way to the modern ladder type and wheel type trenchers.

Modern trenching machinery was first perfected about 1910. It gives low cost excavation plus fast rate of progress. It is a part of almost every pipe line construction job. Except for very small jobs, hand trenching labor is generally found inefficient and uneconomical. If the ground is free of large, heavy obstructions, and not too hard, the modern trencher is very efficient.

Type of Trencher Most Suitable

The type of trencher to use will depend upon local conditions. If the trench dimensions are small, and much maneuvering is required because of restricted conditions, then some of the smaller trenchers will prove best.

Many consider the wheel type trencher is a harder digger than the ladder type. In hard and tough clays, for medium depths and widths, this type is most efficient. These designs are generally limited in maximum widths and depths of trenches excavated, the maximum being about 3½ ft. width and 8½ ft. depths.

Where trenches of greater width and depths are involved, the ladder type must be used. If stones, not too large, are encountered occasionally, the ladder type is more efficient to loosen them, being partly due to the vibration of the boom, whereas the steadiness of the wheel type excavator would not accomplish the same result.

On most of the ladder type trenchers the boom may be telescoped so that the depth of the trench may be increased or decreased with little difficulty.

In any case, if the digging is difficult, then the high-powered types must be used.

Some trenchers are designed for use in cramped quarters, such as narrow alleys, parkways, close to curbs, buildings or other obstructions, etc. With some the boom may be shifted to one side so that the trench may be cut close to side obstructions.

Maximum service is desired in a trencher. They are subject to hard, grueling service, and their design should sacrifice nothing which would affect durability.

With modern trenchers the spoil bank may be located on either side of the machine, or loaded into trucks or on conveyor as desired. The spoil conveyor will place the spoil bank back from the trench sufficient distance to give a good clean shoulder on which the workmen are not hindered in laying the pipe. When extensions are added to the spoil conveyor the desired height of the spoil bank may be secured to care for the earth from deep trenches.

Parson's "Trenchliner"—250—With Offset Boom

(The boom, now operating at center, may be shifted to any desired position across entire width of chute. Thus the trencher may operate on road shoulders, in narrow alleys, close to curb lines, buildings, trees, etc., without harm or difficulty. The spoil bank can be on either or both sides.)

Trenching Methods

If the trench is deeper than the trencher will excavate, there are two methods which can be used to gain extra depth without undue expense. (a) Excavate with scrapers sufficient depth from the surface and the full width of the trencher so that the trencher can excavate to desired grade line. Several feet of added trench depth can be secured in this manner. The spoil conveyor can be lengthened so that the earth may be removed either to spoil bank or to trucks as desired. (b) Under most conditions it is possible to remove about two feet of earth below the trencher cut, and throw the spoil back onto pipe already laid in place. Using two workmen, one with air spade and the other to shovel, this work can be done at a rather rapid rate of progress. Using the combination of these two methods, several added feet of depth can be economically secured.

Estimating Practices in Trenching

The trenching contractor is beset with many difficulties and uncertainties, therefore estimates must allow for many unpredictable contingencies. It is impossible to know exactly just what will be encountered until the trench has been excavated. The trenching estimator must judge many factors to the best of his ability.

A visual survey of many jobs will enable the estimator to determine, with reasonable accuracy, whether the job will present many interruptions; on the other hand, too much dependence must not be placed on such surveys in built-up areas. Questions concerning wells, excavations, etc., made previously in the area will reveal many facts. Many pipe line contractors have suffered great losses by not familiarizing themselves with the underground conditions to be encountered.

Much experience is required to properly estimate different conditions and proper methods of pipe line work. Some estimators estimate the job as close as existing data will permit, then add a percentage for uncertainties—a method but little better than a shrewd guess. The estimator who can accurately determine costs on two or more methods for the same job, is worthy of his hire.

In pipe line construction, the cost of trenching is usually the major item, depending upon digging conditions. The kind of earth involved makes much difference in the unit costs. These costs increase according to the types of earth, somewhat as follows: light earths and sand; loam and light clays; dry, hard loams and tough clays; dense and tough adobes; coarse gravels, cemented gravels; hard caliche; and disintegrated granites. All these materials produce different unit costs.

Labor Costs

Labor costs are not materially increased with the light earths, sand loams and clays, but such costs are increased with the tough, dense clays, adobes, varying with the amount of pipe bedding required. Mud, especially if it is sticky, will greatly increase costs. Unforeseen conditions, such as solid rock, boulders, water, caving soil and even quicksand conditions will greatly increase costs.

The estimate must include: excavation, sheeting, backfilling, equipment rental; moving to and from job; and if water is likely to be encountered, then an allowance must be included for water pumping and disposal.

The labor expense will include foremen; machine runners, helpers or swampers; pipe layers; laborers; timbermen; backfillers; as well as extra roustabouts. The cost of superintendence and supervision can generally be estimated as a percentage of the payroll.

Fixed Costs

Fuel, supplies, and equipment repairs will generally be a large item with most jobs. To determine the fixed costs per day, the contractor must make assumptions which are later adjusted in the light of actual facts. Some depreciate trencher equipment at 60 months' total life; however, many individual pieces of equipment have lasted both much longer and even shorter time than this. Some authorities estimate yearly costs of this equipment somewhat as follows: depreciation, 20 per cent; repairs, 18 per cent; interest, insurance and taxes, 7 per cent; miscellaneous, 4 per cent. Total fixed charges per year—approximately 50 per cent of original cost of trencher. The total fixed costs per year divided by the units of work performed gives the actual job cost for using that particular machine.

About 4 per cent of the payroll should be charged for small tools. Miscellaneous materials required for the work as the job progresses will generally average about 1 per cent of the payroll. Small jobs, unless the management is excellent, will produce high unit costs.

Daily Cost Analysis Important

The cost analysis of trenching for every job should show the width and depth of trench; type of soil; the total footage excavated; the number of cubic yards excavated; the total overhead and operating expense of the trencher; the daily expense of trenching; the footage expense of trenching; and the cubic yard expense of trenching.

The unit costs should separate excavation; pipe laying; back-filling; cleaning up, moving to and from job; and overhead. The analysis should show minimum, average, and maximum day's work and reasons, together with average of all items for the entire job. These data, kept up daily, will show and determine all leaks and losses on the job.

Cleveland Trencher

(Cutting through a soft-rock formation in Texas called the Austin Chalk. Note the clean cut made. Trenchers of the ladder type are also good in shale, consolidated gravel and all but hard solid rock.)

PART II—ROCK TRENCHING

What was said in Part I on trench excavation in dirt may also be almost wholly applied to trenching in rock. Rock trenching is a time and labor consuming proposition. The fact that it is not often encountered probably accounts for the great variation of methods adopted on different jobs. The technical literature contains almost nothing on this subject. Ask the manufacturer's blasting experts and they merely say, "I will get you something on that." (Period!)

System Lacking in Rock Trenching

Most rock trenching jobs have little or no system. Costs are high, progress is slow, and those in charge make little or no endeavor to find the most economical method for that job.

In rock trenching the quality and quantity of the rock will generally determine the proper method of excavation. For economical work it is necessary to give much thought and attention to the job methods.

The types of rock encountered may vary from hardpan to dense, tough granites; each will require a different method of drilling and shooting.

There does not seem to be any current standard practice in the spacing of drill holes. Each foreman seems to have his own pet ideas—very few of which would stand much investigation from an efficiency viewpoint.

Proper spacing of drill holes will depend on the nature of the rock and local conditions, but cut and try methods must be utilized to ascertain the most economical method.

Drilling Requirements

The number of feet of hole to be drilled per cubic yard of rock to be excavated will vary greatly with different jobs, conditions, and job methods. Spacing will depend upon nature of the rock and width of trench. Properly determining this factor requires much ability on the part of the job manager. This determines ultimate unit costs.

For average rock the following table may be used to determine trial hole spacing:

Width of trench (feet)	Number of rows of holes
3	2
6	3
9	4
12	5
15	6

The outside row of holes should be in line with the trench wall. It is seldom that cross-trench hole spacing greater than 3 ft. can be successfully used. At times the longitudinal spacing can be increased to 4 ft. or even slightly more, especially in the wider and deep trenches. The greatest economy is secured in using maximum depth for holes.

The necessity for protecting adjacent structures, whether underground utilities or nearby buildings, will influence drill hole spacing.

If power excavation equipment is to be used, it is seldom possible to blast a single line of holes down the center of the trench. With but one line of holes too much projecting rock remains to be loosened by prying and barring by hand methods, thus greatly increasing costs.

Care must be taken to keep the drill holes clean until they are loaded. If the hole contains debris or water, this is best removed with compressed air. Ice frozen holes may be cleaned out with steam; this also warms the hole sufficiently so that the explosive will not freeze. A wooden plug should be driven into each hole as soon as the drilling is completed, to keep out extraneous materials; this plug also aids in finding the hole later.

A Well Braced Trench

Proper Quantity of Explosives

Determining the proper amount of explosive to use will require trial and error determination. Experience and good judgment helps very much. In any case carefully kept notes and records are of immense value.

In trench blasting only one narrow face is open, therefore more explosive is required than for open surface blasting. The amount and strength of dynamite to properly use will depend upon all the factors mentioned for spacing of drill holes. The amount of explosive required per cubic yard of rock removed will depend upon the nature and type of rock and the method adopted. The amount of explosive per hole may be limited by the necessity for controlling flying rock, excessive noise or vibrations, and danger to nearby underground utilities or adjacent structures of any nature.

Dynamite is generally used for trench blasting; the grade used depending upon the type and quality of rock encountered. The quantity required may range from about ¾ lb. per cubic yard in soft sandstone to 3 lbs. or more in the hard, dense rocks.

Different rocks and formations do not blast alike to meet given conditions. The specifications for the work may limit the amount and kind of blasting that may be done on the job. Oftentimes blasting is restricted due to local conditions.

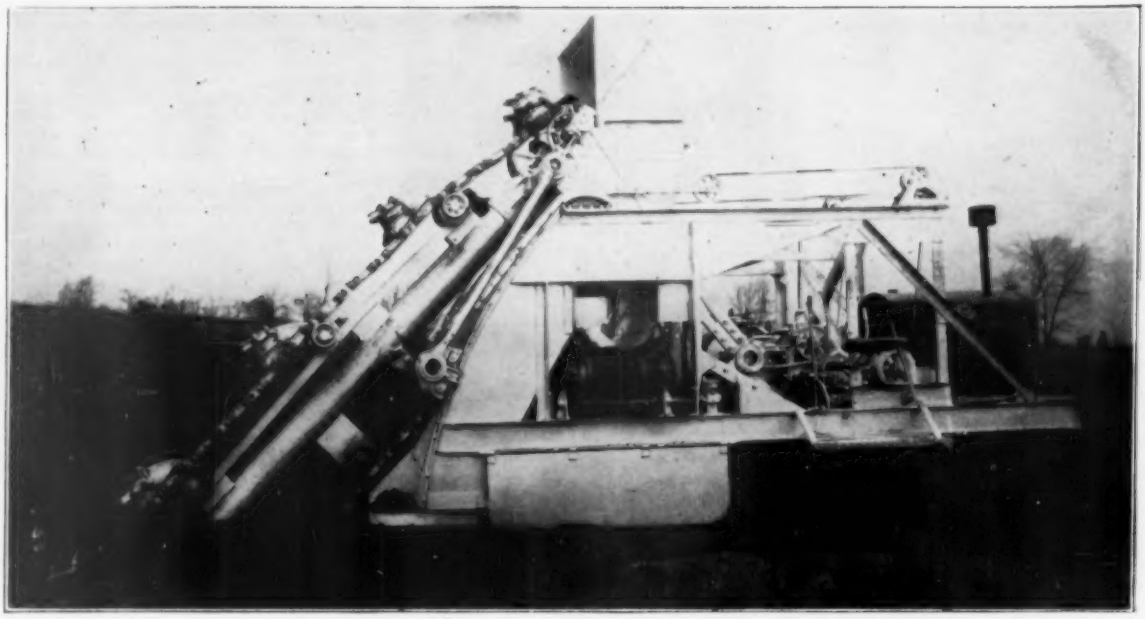
Selection of Proper Explosives

The type of explosive to use will depend upon the type and quality of the rock; local conditions; etc. The greatest waste in explosives is in using a grade or type not suited to the job at hand. A low grade of explosive should be used for soft, weathered rock; to use high grade explosive here, is to waste much of the explosive energy. High power explosives lack propelling power when used in blasting soft rocks.

Too many use only one type and grade of explosive — generally 40 per cent strength. This is poor economy. Some arbitrarily use 60 per cent to secure sufficient shattering and also to loosen rock bound in place. If the rock is not shattered sufficiently, then a higher grade should be used. If the rock is shattered too much, then a lower grade should be adopted for the job.

A high power explosive should be used for hard, firm rock. If the bottom of the hole does not shoot properly, then it may

Koehring's Trench-Hog
(A rugged piece of equipment, useful where the going is tough—boulders, hard shale, blasted rocks, etc.)



Buckeye Model 120 Trencher

(Buckeye also makes a wheel-type trencher satisfactory for water-line trenching, requiring less depth and permissive of faster travel where the going is easy.)

be best to use a high grade explosive at this point. In such cases place the firing charge at the top of explosives so that the explosive gases will tend to concentrate at the bottom of the hole, thus producing greater rupture at that point.

Sufficient shattering must be secured to permit easy removal of the rock from the trench. It is not possible to use ladder type of trenchers for rock trenching, except in the very soft formations. A pull shovel or trench-hoe may often be used to good advantage in rock trenching.

Rock Excavating Equipment

In shallow trenches the rock may be removed by hand. For hand excavation the rock must be broken into small pieces by either blasting or subsequent breakage.

For deep rock trenches the use of drag line or pull-shovel is most economical. These types of equipment are well suited for this work. The rock must be thoroughly broken up, and the wall sufficiently straight not to hang up the shovel. Rocks too large to be removed by the bucket should be hoisted from the trench with chains.

Limestone is easily drilled. It is occasionally found in horizontal layers, and may be blasted like building stone. In seamy formations, the holes must be closely spaced to retain the force of the explosion. Seamy rocks permit the explosive gases to escape and the full effect is not retained in shattering. Seamy rocks, lying at an angle cause the drills to stick and straight walls may be secured in blasting bind in the hole. Relatively smooth and soft sedimentary rocks.

Granite and igneous rocks break out in rough, irregular walls. If the holes are thoroughly and tightly tamped, then the explosive will give most effective results, due to confining the explosive gases. Trap and quartzite are generally difficult to drill.

Two factors should be kept in mind at all times in rock trench excavation: the number of feet of hole drilled per cubic yard of neat excavation; and the amount and strength of dynamite used per cubic yard of excavation; both of which sum up to: cost of breaking up the rock for satisfactory removal.

LAND MEASURE

A Quarter Section of 160 Acres Divided to Show Relationship of Rods, Chains and Feet

A rod is 16½ feet.

A chain is 66 feet or 4 rods.

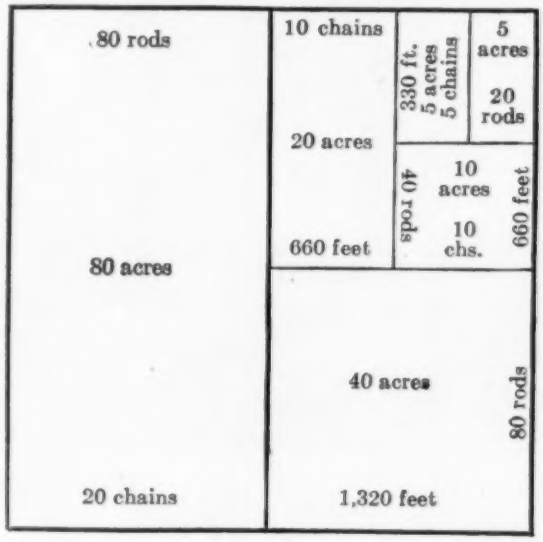
A mile is 320 rods, 80 chains or 5,280 ft.

A square rod is 272¼ square feet.

An acre contains 43,560 square feet.

An acre contains 160 square rods.

An acre is about 208¾ feet square.



Design of Minor Sanitary Sewers

by GEORGE W. REID

Assoc. Prof., San. Eng., Univ. of Oklahoma, Norman, Okla.

AS IS TRUE with most design practices, sewer designers as well as the regulatory agencies have developed sets of minimum standards which have become widely used. These standards are generally good, but they present a real design problem when applied to conditions covering values of such small magnitude that calculated values would be below the minimum.

This principle holds true particularly for the design of minor sanitary sewers which, on the basis of present standards, are sewers serving areas of less than 50 to 60 acres in similar areas in which the available fall is less than 0.4 per cent.

At present, sanitary sewers to serve small areas are generally designed on the basis of minimum grade and size. It is the author's opinion that these sewers should be designed primarily with respect to velocity, cost and accessibility for cleaning.

There is ample evidence in practice to indicate that these are the important criteria. Minimum grade requirements have been established, as well as manhole spacings, by many cities and states in an effort to insure adequate cleaning velocity; but the important thing, so frequently forgotten by the designer, is that these criteria are based on sewers flowing full or at least half full. A typical set of standards is reproduced in Table 1.

If an engineer designs a sewer using grade as the criterion, inspection of Table 1 shows that with less than 0.4 per cent grade available he might well select the next larger size sewer in order to conform to the minimum specifications. The fallacy of this technique is that reduced relative capacity (percentage flowing full) resulting from using a larger sewer may cause less desirable velocity conditions (Table 2) than would have been achieved by using the small section on the given grade, even though the grade would be less than the specified minimum.

Several instances are known where this practice has resulted in 12-inch sewers feeding into 10-inch sewers because of reduced grades. Lift stations are the answer, of course; but they should be used on a planned basis for large areas—not on small areas or small discharges.

If sewers serving small areas are designed on the basis of minimum size, the actual velocity may be so reduced, due to lower operational capacity, that it might well have been better to reduce the size even below the minimum.

Table 3 illustrates the problem of using 8-inch sewer as a minimum size in small areas, with a minimum grade of 0.4 per cent. A normal city block lateral generally will serve ten to fifteen houses, utilizing only 5 or 6 per cent of the available capacity of an 8-inch sewer. This is not based on average conditions, but on estimates of maximum conditions.

To illustrate the importance of these considerations, the following example is given:

Assume it is desired to design a sewer lateral for one city block of ten homes. A topographic survey reveals that only 0.3 per cent grade is available. The actual design flow, q, would be

$$\frac{10 \times 4 \times 70 \times 3}{1{,}440} = 5.8 \text{ gpm.}$$

Setting up the computation procedure of Table 4, the various sizes of sewer and resulting velocities under actual conditions of discharge can be investigated.

The value of v/V is determined from Figure 1, in which q/Q is plotted against v/V; then $V(v/V)$ will give the actual value of velocity in the sewer. It will be noticed that a 6-inch sewer on 0.3 per cent grade will provide slightly better velocity characteristics under the conditions stated than any of the larger size sewers, whereas the minimum grade for a 6-inch sewer is 0.63 per cent.

It will be noted also that the 8-inch and 10-inch sewers will have approximately equal velocities, but the 8-inch sewer would be 10 per cent cheaper to install than the 10-inch one.

This is an example wherein the engineer should be allowed to economize by putting in an 8-inch sewer on a grade less than the standard of 0.4 per cent, rather than the next larger size.

TABLE 1
Minimum Grade—Size Relationships

Size, Inches	Fall, Ft/100 Ft
8	0.41
10	0.28
12	0.22
15	0.16
18	0.12
20	0.10
24	0.08

TABLE 2
Relationship of Sewer Depth to Sewer Velocity Flowing Partially Full*

Depth as a Percentage of Full, $d/D \times 100$	Velocity as a Percentage of Design Velocity, $v/V \times 100$
10	40
20	62
30	78
40	90
50	100
60	107
70	112
80	114
90	112
100	100

*Using Manning's formula.

TABLE 3
Relation of Minimum Sewer Capacity to Number of Homes Served

Percentage of Design Capacity $q/Q \times 100$	Homes Served*
1	6
5	30
10	60
25	150
50	300
100	600

*Assuming unit flow of 70 gpcd and Q_{av} to Q_{design} of 3 with four persons per home; 8-inch sewer on 0.4 per cent grade.

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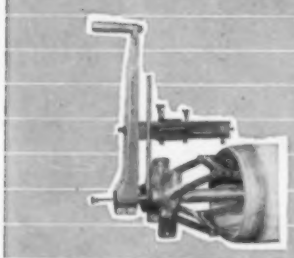

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These velocity values actually should be increased to allow for the decrease of tractive requirements as the sewer flows partially full. The approximate values are given in Table 5. In the foregoing problem the adjusted velocities would be of the order of 0.60/0.65 = 0.92 feet per second.

In dealing with small areas, actual house counts, rather than population per area values, should be used to ascertain the correct discharge. The U. S. Bureau of Standards measured house sewage flows and arrived at the following maximum for coincident discharge—at least once in 24 hours:

Number of Houses	Max. Coincident Daily Discharge, GPM
1	7
2	12
3	17
4	21
5	25
10	38
20	57

Using these values for discharge in the previous illustration, and adjusting the velocities, would raise the velocities as shown in Table 6.

If these values are reliable, then the engineer has roughly a velocity safety factor of three. In any event, the foregoing calculations indicate that almost any of the sizes will do equally as well velocity-wise for the areas under consideration. From the standpoint of price, however, they will rank in ascending order of 1.00, 1.15, 1.25, and 1.40, respectively. The savings on a single lateral of 8-inch over 10-inch might be from $150 to $200 at current prices.

It might be argued that an 8-inch sewer on a 0.4 per cent grade, plus a lift station, would have been the proper solution of the problem given. But inasmuch as a lift station to handle such low flows would be a nuisance, and would cost, if built on minimum specifications, approximately $3000, it should be resorted to only when a larger area is involved.

The technique of approach illustrated uses only a Manning formula chart, and Figure 1 can quickly advise an engineer as to which of several sewers will provide the best velocity characteristics at the least cost when dealing with small areas and low grades.

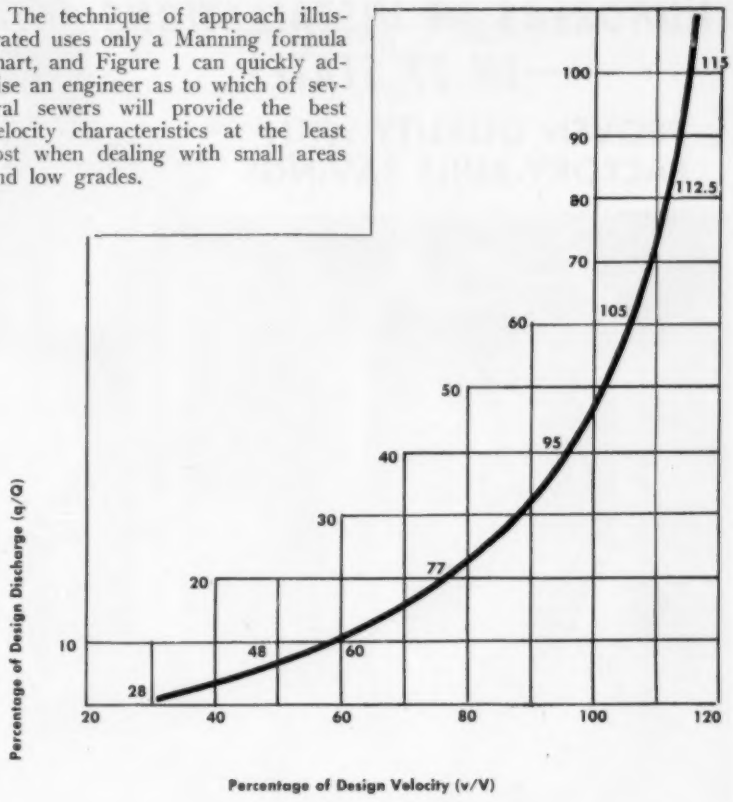

Fig. 1—RELATIONSHIP of discharge and velocity for sewers flowing partly full.

TABLE 4

Computation Procedure for Study of Discharge and Velocity for Various Sizes of Sewer

D* Inches	Q* GPM	V* Ft/Sec	q/Q Per Cent	v/V Per Cent	v Ft/Sec	Increased Cost Per Cent
6	140	1.5	9.9	45	0.68	0
8	290	1.9	1.75	35	0.61	15
10	520	2.1	1.20	30	0.60	25
12	850	2.4	0.62	22	0.53	40

*From a Manning formula chart.

TABLE 5

Variation of Carrying Velocity with Percentage Flowing Full

d/D Per Cent	v/V Per Cent
100	100
50	80
40	75
30	70
10	65

TABLE 6

Increase in Velocity When Adjusted for Maximum Coincident Daily Discharge

D, Inches	q/Q	v/V	V	V Adjusted for d/D
6	64.0	106	1.6	1.6
8	11.0	62	1.2	1.7
10	7.7	55	1.1	1.7
12	1.0	31	1.3	2.0

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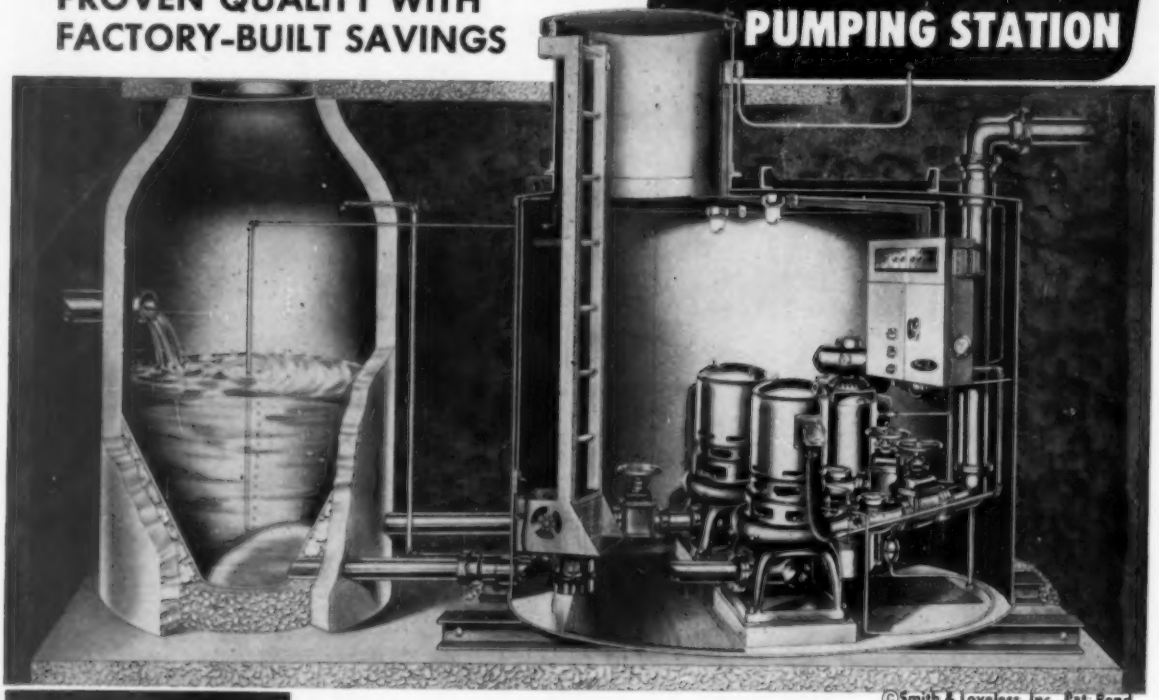

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Design of Sewage Pumping Plants

A practical method of estimating present and future capacity needs

By RAYMOND G. MARTIN
Asst. Civil Engr., Bur. of Engineering, City of Los Angeles, Calif.

ONE might say that the design of a sewage pumping plant is only a series of estimates. Actually it is a pyramid of estimates. Everything from the area to be drained to the final construction is based on calculated estimates.

Unfortunately engineering is not perfected to the state of being an exact science which would make the design of a pumping plant a simple mathematical problem. Published literature shows that opinions differ greatly in the methods used to arrive at these estimates.

The following discussion includes four items which must be estimated in the design of a sewage pumping plant:

1. The *design capacity* of the plant
2. The *flow rate* of the sewer system
3. The *pump capacity*
4. The *reservoir capacity*

Sewage pumping plants can be broken down into two classes: one without storage, the other with storage. The type without storage is suitable in cases where there is a large flow of sewage with a small change in rate of flow. The type with storage is suitable for any type of flow.

The methods which will be discussed are well suited for economical design of a pumping plant using storage. Also, some of these methods apply as well to a pumping plant without storage.

Design Capacity

The first thing that must be estimated is the *design capacity* of the plant. The design capacity is defined as the planned total daily flow through the plant. This capacity is based on tributary area, the limits of which are defined by the natural terrain or the sewer layout.

The flow from any given tributary area may be estimated in either of two ways:

1. Based on population;
2. Based on zoning characteristics.

The first method is best suited for residential areas, while the second method is best suited for commercial and industrial areas.

If the past and present populations are available in the Federal census, the future population can be estimated by expanding the population along a biological growth curve.

If the estimates are to be based on zoning, consideration must be given to terrain and environment. This means accounting for such features as rivers, hills, transportation, and utilities.

The basic flow units, such as G.P.D. and C.F.S. per acre, may be based on actual measurement of similar areas, such as sewer gaugings and previous pumping records, or on zoning coefficients when available. The flow to be considered should be the average of the three peak months of the year; for the Los Angeles areas these are January, February and March.

Flow Rate

Having arrived at an estimate of the average daily flow, it is now necessary to determine how this flow will arrive at the site of the pumping plant. The best method to do this is to draw a flow rate curve as illustrated in Fig. 1.

The flow rate curve is a curve which defines the rate of flow at any hour of the day. The average rate of flow is shown on the curve.

The curve shown here is a typical curve of a normal rectangular residential area. One extreme curve may be found in the flow from an Army

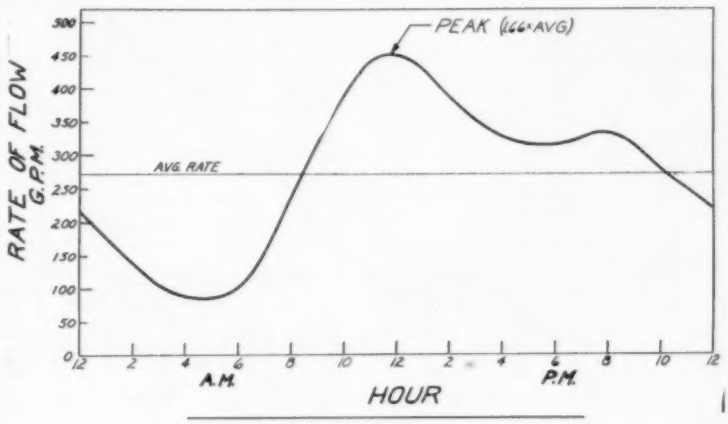


Fig. 1—RATE CURVE for sewage flow
This curve is typical of a normal rectangular residential area.

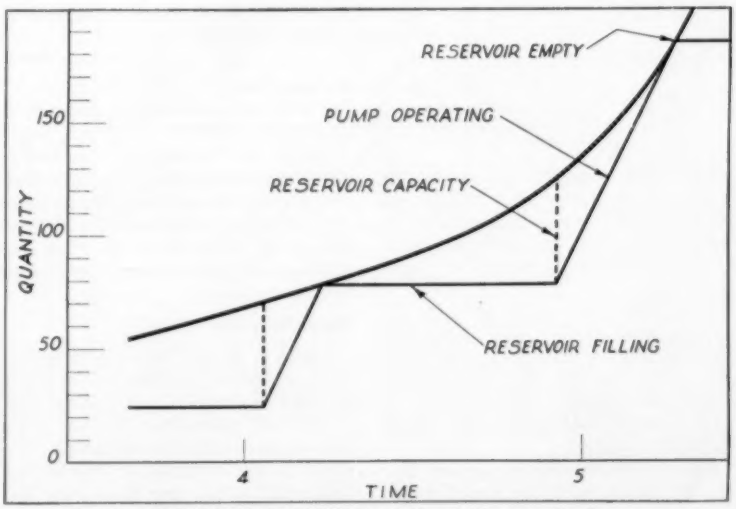


Fig. 2b—EXPANDED MASS CURVE Fig. 2a for plotting pumping frequency
Pump operates at fixed rates when reservoir is filled to capacity.

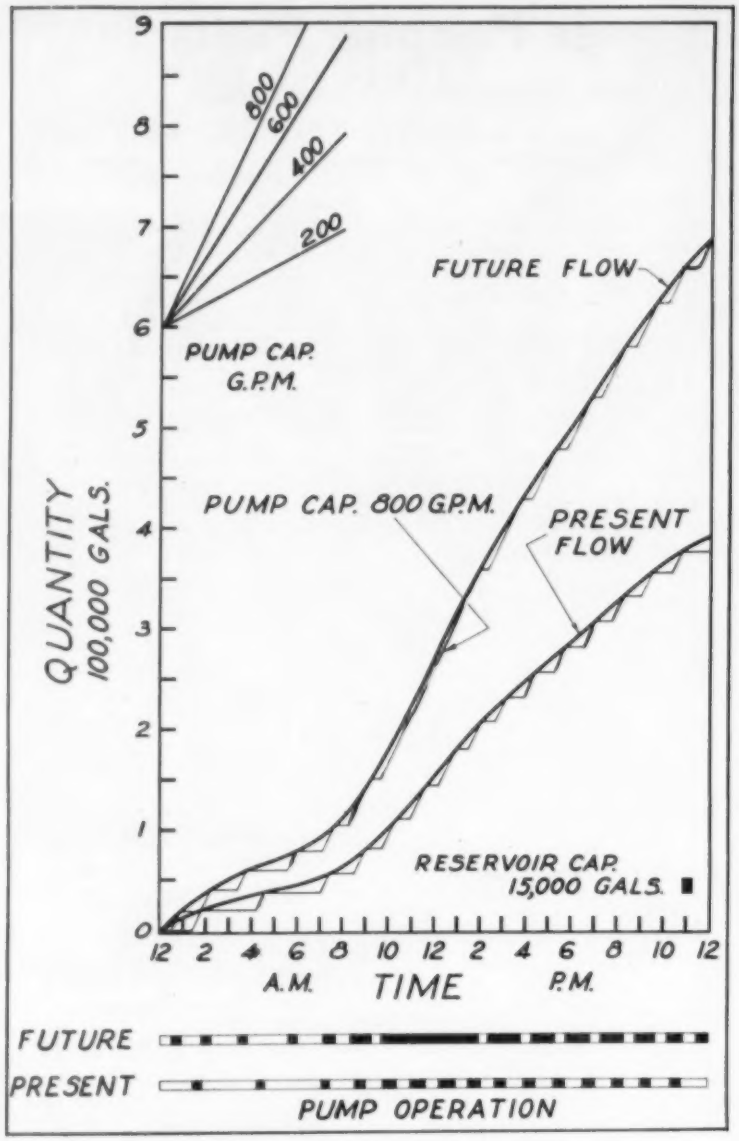


Fig. 2a—MASS DIAGRAM developed from rate curve
Slope of curves is equal to rate of flow (ten year future is 1.8 times present). Below: Solid dashes illustrate pumps in operation.

camp where exaggerated peaks are found every time the bugle blows. Another extreme case is found in the flow from a 24-hour packing plant where the flow is constant at all times of the day.

The peak factor is a ratio of the average flow to the peak flow. The curve in Fig. 1 has a peak factor of 1.66. Note that the curve also shows a secondary peak in the evening. A normal curve has a peak factor varying from 1.3 to 2.2.

The rate of flow from a given area may be estimated from actual measurements, or by considering the time of concentration of the sewer system, or by comparing the given area with other areas of similar characteristics.

The future flow rate may be estimated by expanding the flow rate curve by the increase calculated in the design capacity.

Mass Diagram

Having established the flow rate both present and future, a mass curve or mass diagram can be drawn, from which both pump capacity and reservoir capacity can be estimated. The mass curve illustrated in Fig. 2a was developed from the flow rate data comprising Fig. 1.

The mass curve is defined as the accumulated inflow at the pumping plant at any hour of the day, and is derived by integrating the flow rate curve from any zero hour, in this case considered to be 12 o'clock midnight. This means that the area under the flow rate curve between zero hour and any time of the day is equal to the ordinate of the mass curve. Another way of stating this is that the mass curve defines the total amount of sewage that arrives at the pumping plant between zero hour and any specific hour of the day.

Thus the slope of the mass curve equals the rate of flow. It is these two features that make it possible to plot a picture of the operation of a pumping plant and therefore pick a good combination of pumps and reservoir capacity.

At this point, I should add that it is necessary to estimate the life of the structure and pumps. A reasonable life for the structure is 40 years. However, some engineers like to use 50 and 60 years.

Authorities differ considerably on what is a reasonable life of a sewage pump. For secondary reasons, ten years will be considered the life of the pump in this example.

As you can see on the diagram (Fig. 2a), there are two curves. One is the present flow, and the other is the flow ten years from now, or 1.8 times the present flow. For simplicity, this is to be considered the ultimate flow.

Pump and Reservoir Capacity

An expanded section of the mass curve (Fig. 2b), shows how the pump operation can be plotted directly on the curve. As mentioned before, the ordinate of the curve equals the accumulated inflow. The slope of the curve equals the inflow rate. The pump capacity is the slope of the pumping line. The storage capacity is a fixed ordinate. The time is measured on the abscissa.

Starting at a point on the mass curve, a horizontal line is drawn to the right. This represents the filling of the reservoir; it is considered full when the difference between this line and the curve equals the storage capacity, a vertical dotted line. From the point on this line where the reservoir is full, a line is drawn with a slope equal to the pump capacity. This line represents the pump in operation. At the point where this line intersects the mass curve, the pump shuts off and one cycle is complete. The picture now shows the time that the pump is idle and the time that the pump is in operation.

To help in picking a suitable pump, a series of pump capacities is drawn

in the upper left hand corner of the diagram (Fig. 2a) making it easy to choose a pump capacity which closely matches the mass curve.

The example shows the plotting of pump operation for the entire day. This is done for a given storage capacity and pump capacity. If the operation is not suitable for the capacities chosen, they may be altered and the operation plotted again. This is done for both present and future curves.

If a straight line is drawn between the two end points of the mass curve, it would represent a pump capacity which would just handle the total daily flow and never shut off. However, a quick glance at the storage capacity necessary will show how impractical this combination would be.

At the bottom of the diagram you can see two dashed lines. This is done to show a clear picture of the operation. The solid area represents the pumps in operation. Thus a solid line would indicate the pump running continuously.

In this manner the pumps and reservoir are actually fitted to the sewage flow, thus making an economical design.

This method is not new, for it was used in other ways long before I was born. However, I feel that it still provides a good straightforward approach to the design of a sewage pumping plant.

Garden Hose for Pump Packing

An economical and long-wearing material

By WM. H. HIGGINS
Supv.-Mgr., Ewing-Lawrence Sewerage Auth., Trenton, N.J.

IN our sewage treatment plant we have two sludge pumps of the piston type that leaked very badly. Our pump room floor and pumps were always messy and wet which also gave an impression of poor housekeeping. The packing would again leak very badly a week after renewal and within four to six weeks would be completely worn out. This frequent changing of packing naturally runs the maintenance costs of these two pumps extremely high; in fact, way out of proportion to costs of maintenance of other equipment.

Having heard or read of the use of garden hose for packing, we decided to try discarded 5/8" garden hose in place of the 3/4" packing, after having tried several types without much to choose between any of them.

Preparation and Use of the Garden Hose

You first "soak" the hose thoroughly in oil so it will slide more readily; then, cut it to the approximate length. A piece of wood about 2" wide and 1/2" thick, with the length most convenient to the user, is lowered to the bottom of the stuffing box and marked to indicate the top of the stuffing box. With this marked stick, when the first ring of packing is in, you will be able to tell whether it is "driven" all of the way down in the box.

Using the above piece of wood, the length of hose is placed into position and "pounded" in about an inch or two. Here an exact measurement is made of the hose length and *cut perfectly square*. This is important in order that the hose joints will bind very tightly together when hose is pounded into its final resting place. It might be well to note that we seem to treat the hose very roughly by pounding or driving it into place. This hose is ring shaped and we are trying to fit a round object into a container made for a square object. I feel that it is necessary that it be understood that this garden hose will not fall into place or be easily pushed into place. A lot of effort will be needed to accomplish this job.

Of course, the joints of the hose rings must be staggered and each ring put in exactly as the first. As each ring is put in it will be necessary to use a pinch bar or the like in order to get this hose to start down the stuffing box, because of its tight-fitting nature. In other words, you have to pry the hose into its initial start down the sides of the cylinder and then it is pounded down with the piece of wood mentioned previously.

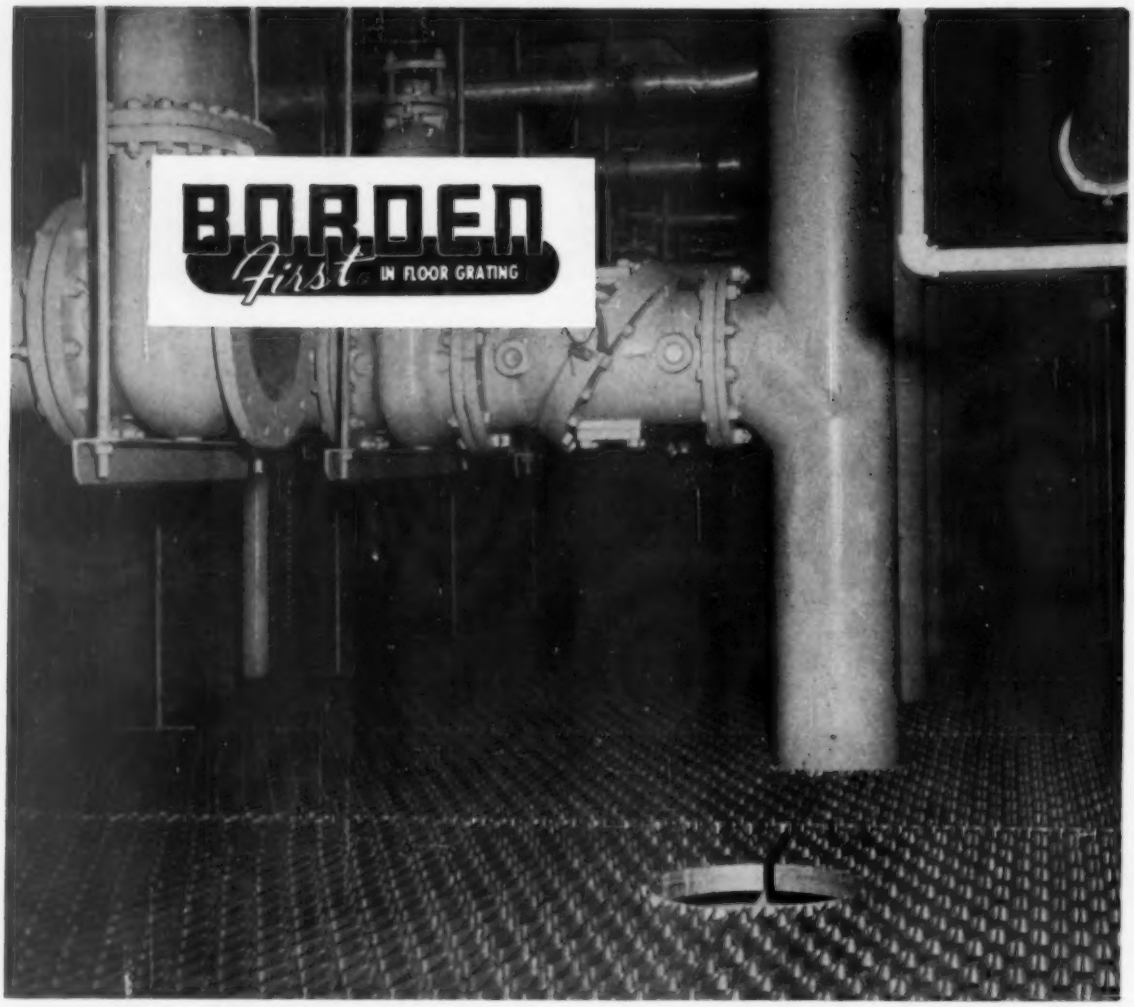
In using scrap hose there might be a slight variation in its size even though it is called 5/8" hose. We found in one pump that four rings were needed and only three in the other. Eventually (possibly in two to three months) the fourth ring will have to be added.

Don't Be Discouraged

The pumps will leak for a short period of 2 to 3 days. Be patient and you will find the leakage will stop. Then a slight backing up of packing glands might be necessary. If the pump seems to be laboring, this is the clue that the packing is too tight. The hose will in a short time square up just like regular packing. Be sure that oil is kept in the packing gland reservoir as customarily done when regular packing is used. We have found that rubber hose lasts longer than plastic hose.

In conclusion, I would like to inject a thought that I have had on my mind since a remark was passed that only a "cheap" outfit would use garden hose as a substitute for good packing.

I sincerely believe as an operator of a sewage treatment plant that we are employed not only to run the plant properly, but also to use a little discretion and practice economy in purchasing parts, etc. We, as operators, must realize the cheapest is not always the most economical nor is the dearest always the best in regards to materials. In sewage treatment those who care for and maintain equipment should always be open for new ideas, and there is a real need for new ideas. We therefore are obligated to try new ideas and experiments.



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Paint Protection of Sewage Works Structures*

By W. T. McCLENAHAN

Principal Construction Engineer, The Sanitary District of Chicago, Ill.

SEWAGE works structures are everywhere depreciated by persistent and damaging attacks by the plant surroundings. The mitigation or stopping of these attacks is one of the engineer's most urgent and continuing problems. How can this depreciation be stopped, or at least controlled? The answer to this question requires a very careful study of three factors:

1. A study of the nature of the conditions prevailing about the sewage works which bring about the deterioration.

2. A study of the way these destructive conditions affect the different materials of construction.

3. A study of the various types of protective coatings available and suitable for resisting these conditions.

The writer (1) has already outlined the corroding conditions peculiar to a sewage works in a previous paper. It is, therefore, unnecessary to repeat that discussion. The way various metals react to the plant conditions causing deterioration has also been discussed in detail in another paper (2). Anyone interested in these subjects is referred to these two papers and to numerous other articles on this and related subjects in engineering literature.

The present paper takes up the subject of paint protection and dwells particularly upon the Chicago Sanitary District experience with priming and top coat paints on metal used in and about sewage works.

It should be stated that paints and painting systems which can be used for these purposes in sewage works service are legion, and new and better ones are being continually introduced. It will not be possible, therefore, to discuss the merits of all paints and painting systems which might be used or to cover the painting of surfaces other than metal.

Preparation of Metal Surface

The success of a painting job depends greatly upon the care with which the cleaning work is done. The amount of cleaning work required depends upon the conditions of the metal surface, the exposure, and the type of paint to be used.

On new work it has usually not been thought necessary to completely remove the mill scale, but in such case the shop coat must be applied before the mill scale has started to come loose. Otherwise, much trouble will be experienced with the scale "popping" off afterwards and bringing the paint with it.

Undamaged mill scale, especially when it is thin, is of itself quite protective, but thick mill scale, especially when it has been exposed to the weather, almost always contains moisture and it is the moisture which causes most of the "popping."

Some alleviation of this trouble may be realized if the surface is flamed just before it is painted to bring off the thickest scale, dry the steel, and drive off the moisture from under the edges of the tight scale where the moisture often hides. Nevertheless, if the scale is heavy, even this expedient may not prevent "popping" afterwards when the structure flexes under stress or is subjected to rapid changes of temperature.

Sometimes it is better practice to let all of the mill scale weather off before the surface is painted than it is to try to paint over a badly damaged or very thick mill scale. This procedure, however, takes considerable time to complete the scale removal and usually takes from nine months to a year to secure a scale-free surface suitable for painting. Otherwise, the engineer may find it more expedient to paint the steel and expect to touch it up frequently afterwards whenever and wherever the scale pops off. The alternative is to sandblast or pickle the surface.

It should be pointed out, however, that there are definite limits to the practicable use of sandblasting about a sewage works that is in operation, and pickling is not generally applicable to steel that is erected. Weblike structures are very expensive to sandblast and, moreover, sandblasting in the vicinity of pumps, blowers, motors, and any other machinery may do damage to the machine bearings if extreme care is not taken to protect them. For these reasons sandblasting in the Chicago Sanitary District's work is usually confined to the inside surfaces of tanks and metal surfaces in screen houses and grit chambers where damage to equipment is not so likely to occur and where this treatment seems to be especially needed.

The best way to prepare a previously painted surface for repainting depends greatly upon where the work is and what the present condition of the surface is. If the condition about the surface is normally dry, such as is usually the case at a bridge, an office building, a laboratory building, or a normal pump and blower house (in fact, at practically all sewage works structures except those which enclose open sewage or water), the cleaning and preparing work may very well be covered by the following specifications:

"All metal surfaces to be painted shall be sound, clean, and free of harmful scale, rust, dust, dirt, oil, grease, moisture, and other foreign matter which will in any way detract from the life and usefulness of the coating.

"Oil, grease, and soap accumulations shall be thoroughly removed by means of suitable solvents or by use of trisodium phosphate or strong caustic soap, followed immediately by a thorough washing of the surface with clean water. . . .

"All rust, loose scale, loose paint, and other debris shall be thoroughly removed and all damaged paint and rust pits shall be scraped out, back to sound material, using scaling hammers, chisels, scrapers, hand or motor driven wire brushes, power wheels, or other such tools as may be suitable and effective. . . . Re-entrant angles and inner corners and around rivet heads and bolt heads and nuts shall be scraped out clean and the entire surface thoroughly wire brushed."

The District specifications require use of the cleaning tools "in such a way as will not unduly scratch or score the metal surface," because the scoring may damage the paint afterwards. Sharp metal edges are specified to be dulled with a file or a grinding wheel, because when a paint dries volatile escapes and as certain oxidations over these sharp edges it pulls tight due to a shrinkage in volume taking place as the and polymerizations take place in the vehicle and certain pigment-vehicle reactions (largely those of zinc oxide) cause reduction of volume. Also, under varying exposure conditions certain physical changes in volume take place which are due to wetting and drying, heating and cooling, and freezing and thawing at different times. These changes in volume cause high stress in the film at the sharp edges so that the film often breaks.

If the above specifications are conscientiously carried out, the preparation of the surface will usually be sufficient, except where the atmosphere is normally highly humid. The paint may not last quite so long when the steel is thus cleaned as it would were the surface to be thoroughly sandblasted, but it will usually give a satisfactory paint life.

Steel in submerged locations has not been found to be particularly difficult to protect as compared to steel in humid atmospheres, especially where sewage gas is present, except that oil, grease, and soap accumulations and oxygen at the water line in the submerged locations, together with mechanical damage from floating matter, introduce problems. To overcome these special conditions in submerged locations the paint must be specially designed for that kind of service.

If the surface of the metal tends to accumulate moisture—as it does on steel sash and doors and on the building framework, handrails, stairs, and equipment in a screen house or grit chamber where warm sewage is in direct contact with the atmosphere to saturate it and the metal acts as a sort of condenser to collect the moisture from the humid atmosphere and this moisture tends to absorb the carbon dioxide to form carbonic acid and the hydrogen sulfide and oxygen to form sulfurous and sulfuric acids—it will be very difficult to get the metal sufficiently dry and free of these acids to secure a good clean surface and a lasting bond for the paint.

If there is a film of moisture left on the surface, the paint will not properly "wet" the metal and if it doesn't wet the steel it will not bond well to it. In addition, the moisture and acid left on the surface will spread damage underneath the film.

Removal of this moisture and acid has been tried by washing the surface with solvent and then immediately wiping the surface dry with a clean dry rag. However, current thinking is that in such places only complete removal of all old paint and scale by sandblasting or otherwise will be sufficiently effective to secure a reasonable paint life.

If it were safe to use, flame cleaning of the surface just before painting would very effectively dry the steel and extract the moisture from beneath the edges of the old paint and scale. Moreover application of the paint to the steel immediately—while the steel is still warm—accomplishes a baking of the paint onto the surface, which assures greater paint density and better adhesion to the surface. However, the presence of methane and gasoline fumes about a sewage works, to say nothing of the volatile from the paint itself, makes flame cleaning inadvisable in confined quarters. Moreover, if flame cleaning is used and the mill scale is thick and already coming off,

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* Abstracted from S. & I. W., Vol. 24, p. 1 (1952) by permission.

the flame treatment may need to be supplemented by a grinding of the surface to produce a smooth, even surface before painting. Otherwise, the painted surface will show unsightly islands of tight mill scale beneath the paint film.

Use of Phosphoric Acid Coatings

Where it can be done, Parkerizing or Bonderizing of steel window sash and doors, especially those in the outside walls of screen houses and grit chambers and other places where the humidity always runs high, is advantageous, if done just before the shop coat is applied. If this is done there will be less blistering and corrosion of the painted surface. Under certain conditions a phosphoric acid wash is used. The present Chicago Sanitary District specifications for this wash (SDC No. 313) call for a phosphoric acid content in the wash as applied, expressed as H_3PO_4, to be 15 per cent by weight of the diluted solution.

The Sanitary District has done considerable work with these wash coatings applied to steel in various conditions of cleaning and will do more as time permits. Certain impressions have been developed with regard to their use, as follows:

1. It is not believed that a combination of phosphoric acid and chromic acid is as good as the use of phosphoric acid alone. This is at variance with the findings of the Bureau of Standards, as reported in "BMS 44" and "BMS 102."

2. It is not believed advisable to apply a phosphoric acid wash in a repaint job where the old paint is not completely removed. There is considerable question as to the advisability of thus treating even new steel with the acid where the mill scale is not removed.

3. Some proprietary types of phosphoric acid washes do not seem to "wet" the steel very well. The acid seems to draw itself together so that the action on the steel is quite non-uniform.

Metal Priming Paints

The most important paint in a drying oil painting system is the first or prime coat. Other paints in the system are, of course, important, but the efficiency of the entire paint job is to a considerable extent determined by the effectiveness of the prime coat. Its composition, thickness, adhesion to the steel, and suitability for the purpose are, therefore, all important considerations.

To be of universal service on metal about a sewage works, an ideal priming paint of the drying oil type must serve two very distinct purposes, as follows:

1. It must thoroughly gasproof and waterproof the surface; that is, it must not only be impervious to moisture and acids, but it must also be gastight against hydrogen sulfide. The hydrogen sulfide gas has a very small molecule and will penetrate most paint films. If the gas penetrates, it attacks the steel and forms iron sulfide. This formation, of course, destroys the paint bond to the steel and when the bond is lost the loose paint is more easily damaged by abrasion. The prime paint also must not soften appreciably when covered by accumulations of oils, greases, and soaps, nor be easily damaged by the abrasion of floating matter, which usually accompanies these oils, greases, and soaps.

It must not only be impervious to its surroundings, but it must also furnish good bond of itself to the steel and itself provide good bond for the top coats. These several physical qualities are largely afforded by the vehicle, although the pigment does add considerably to the quality of the paint and its durability. The nature of the vehicle found most serviceable under these conditions is a 25-gal. para-phenyl-phenol-tung oil varnish.

The pigment adds to the protective value of the paint film by increasing the paint density. In the District's experience a pigment volume of from 30 to 35 per cent of the dry paint volume affords the greatest usable density for the primer. The percentage seems to vary somewhat with the amount and kind of grinding. For instance, grinding SDC No. 251 paint in a ball mill for 18 hr. permits use of more pigment than does the ordinary grinding on a roller mill. In fact, such fine grinding definitely requires use of more pigment in order that the surface be not so smooth that top coats will not adhere well to the primer.

The size and shape and, to an extent, the composition of the pigment also affect the performance of the paint film. For instance, it has been found that mica (and especially graphitic mica), when used in moderate amount, adds considerably to the life and usefulness of a metal priming paint.

2. A second, even more important function of the prime coat is to inhibit corrosion of the steel whenever the corroding liquids eventually get through the paint film to the steel, as they inevitably do.

A number of pigments function well in this respect. The best known and most used inhibitors are zinc chromate and basic lead chromate (American vermilion). Red lead has also been classed among the inhibitors, but its most useful contribution to the paint formulation is thought to be its furnishing of a tough, impervious, and strongly adherent lead soap.

It should be pointed out that a priming paint which serves well under one set of conditions may not do at all well under another set. For instance, a bridge is only occasionally wet by a rainstorm. Between storms the protective paint, whatever it is, has a chance to dry out and, to an extent, recover its imperviousness.

Moreover, at a bridge there is no hydrogen sulfide to penetrate the film to destroy the bond of the paint to the metal or oxidize to sulfurous and sulfuric acids to enter breaks in the film and spread damage underneath over wide areas. In the normal situation there are no oils, greases, and soaps present to soften the paint. Steel in such a structure, therefore, presents a much less difficult condition for paints than does steel in many locations about a sewage works, where the paint remains damp practically all of the time, where hydrogen sulfide gas is abundant to bore through the paint film to the steel and there destroy the bond of the paint to the steel, or in another situation where oils, greases, and soaps, together with mechanical damage, are encountered to cause paint failure.

The presence of these more severe conditions in a sewage works necessitates a somewhat different approach to the painting problem than where the conditions are milder. The vehicle, in particular, must be more highly resistant to these untoward conditions in a sewage works than is necessary for paints used on a bridge and on the steel of most buildings.

Red Lead Paints

When a priming paint is mentioned, one naturally thinks of a red lead and oil paint —and for most situations a red lead and oil paint does make a very satisfactory metal primer. Such paints have been used with success for years, even on ship bottoms and inside water tanks, where the conditions would certainly seem to be most unfavorable. They in time past constituted the best priming that was known and they even yet furnish fairly good protection. In recent years, however, a number of other paints have been developed which have gained considerable popularity for the more severe conditions of service.

Why has red lead paint been so satisfactory in the past? There are several reasons for this. In the first place, the red lead pigment enters into the very pores of the iron in a way that no other pigment seems to be able to do. It there seems to become an integral part of the metal so that without use of considerable solvent it cannot be removed without bringing some of the metal with it (probably due to the formation of a basic combination of red lead and iron oxide). Its bond to the steel, therefore, is very good indeed. Moreover, its lead soaps are tough and flexible and quite impervious to moisture. Evans (3) and others feel that red lead also affords some inhibition of corrosion. All of these factors combine to make red lead paints quite satisfactorily protective.

To increase the imperviousness of their red lead paints for use on ship bottoms and on the inside surfaces of water tanks, engineers have often added up to 15 per cent by weight of the pigment litharge. The litharge reacts with the vehicle to increase the lead soap in the film and it is this soap that decreases the permeability. Aside from the possible danger of causing lead poisoning from this practice when the tank is used for drinking water (which danger, however, has not been found to be a serious risk, especially where the red lead is covered by suitable top coats), there is the objection that the litharge cannot be safely introduced into the paint in the grinding because the paint will almost certainly harden in the containers if kept stored for any length of time. It must be added to the paint in the field and that increases the amount of inspection necessary to make sure that the addition is properly made.

Some recent red lead primer specifications call for from 5 to 20 per cent by weight of the total pigment to be zinc chromate, which is added to the grind. This inclusion undoubtedly improves the paint as a primer.

Aluminum distearate has also been added to the paint. The purpose of this pigment is to prevent hard settling in the can, which is often a troublesome matter with red lead paints. For that purpose it is quite effective, but it is used at some sacrifice of the water resistance.

Many red lead specifications include a considerable percentage of red iron oxide in the formulation. This pigment, if finely ground and used in moderate amount, improves the flow-out qualities, but adds nothing otherwise to the paint but color, density, and decreased cost.

Some engineers use varnish vehicles in their red lead paints. These varnishes have been of the alkyd or phenolic oleoresinous types. Presumably because of the prevalence of moisture about the Sanitary District plants, the alkyd varnishes have never been found to be any better, if as good, a vehicle in red lead paints as is straight linseed oil. (For the phenolic varnishes see Federal Specifications TT-P-86a IV.)

Those who wish to further pursue this subject of red lead primers are referred to the Red Lead Technical Committee of the Lead Industries Association, 420 Lexington Avenue, New York 17, N.Y., which has assembled a list of some very good formulas used by various governmental agencies and industrial concerns.

Zinc Dust-Zinc Oxide Primers

Zinc dust-zinc oxide paints have been found very useful for painting new galvanized sheet metal and for touching up the threads and damaged spots of new galva-

nized pipe, but the District never uses it under water. It has been found that zinc dust-zinc oxide paints serve very well as a touch-up prime coat in a repaint job to be finished with one coat of aluminum, and also for an all-over prime coat where that is necessary under the one coat of aluminum.

The New Jersey Zinc Company several years ago did a great deal of research upon zinc dust-zinc oxide paints and from its findings recommended that the vehicle should not have an acid number greater than 4. Because it is the zinc oxide which reacts with the vehicle, it behooves the paint formulator to add zinc oxide with discretion. Nevertheless, some zinc oxide is apparently needed to harden the paint, for zinc dust paints tend to dry rather slowly. The acicular type of zinc oxide has generally been used by the Sanitary District of Chicago because its reactions are somewhat slower than are the reactions of the powder varieties.

As the paint ages, much of the zinc dust oxidizes to zinc oxide so that such paints tend to become harder and more brittle as they grow older. For that reason, some litharge can be used advantageously in the paint to increase the toughness retention of the film. The addition of mica and aluminum distearate helps to prevent hard settling in the container.

A zinc dust-zinc oxide formulation finding favor with the District is as follows:

ZINC DUST-ZINC OXIDE PAINT

Pigment Composition	Per Cent By Weight
Zinc dust (ASTM D 520-47)	70
Zinc oxide (ASTM D 79-44, acicular type)	16
Litharge	2
Mica (water ground or graphitic type)	10.5
Aluminum disterate	1.5
Total	100

VEHICLE

For outside service—M body linseed oil (max. acid value 5)

For damp inside service—50 gal. para-phenylphenol varnish similar to V37.25 later described, but with viscosity D to E at 55 to 60 varnish solids.

VOLUME RATIO OF DRY PAINT

30% pigment.....70% non-volatile vehicle

In addition to thinner and drier to each 100 gal. of paint as made there is added an amount of lecithin (Yelkin TTS brand) as a wetting agent equal to 0.5 per cent, and an amount of 8 per cent zinc naphthenate equal to 0.2 per cent, of the weight of the solids in the vehicle.

SDC No. 251—Red Metal Primer

In plant construction it is always convenient to standardize on one priming paint for use everywhere, irrespective of where the steel is to be used. Top coats applied after erection can be varied according to the location to combat the peculiarities of the exposure, but one cannot very well tell the fabricator to vary his shop coat on different parts of the work according to where the steel is to be placed. Such instructions, if given, would result in endless confusion and countless errors. Even in maintenance repainting work it is less bothersome to stock up with one type of priming paint so that the painters can use it everywhere. This practice reduces the amount of stock necessary for the storekeeper to have on hand. Such a paint, however, must be designed for the worst conditions encountered if it is to be generally applied.

After several years of experimenting the Sanitary District has standardized on a single metal primer for general use which has given very good service, except that it does not seem to be suited to use in very damp atmospheres such as are encountered in screen houses and grit chambers and also on the underside of the roof of water tanks, where it appears necessary to completely sandblast the surface and paint it with some such paint as the WPI wash primer of the vinyl coating system, which is described later. This special paint seems to be the only practical painting system yet tried which will endure these severe conditions.

The red metal primer also is not suited to painting new galvanized surfaces, where zinc dust-zinc oxide paints have proven better. Otherwise, the red metal primer has been found to outlast most other paints, even in submerged locations, if it is properly applied to properly prepared surfaces and properly covered by suitable top coats to protect it.

The paint formulation used by the Sanitary District is as follows:

SDC No. 251-49 RED METAL PRIMER

Constituent	Per Cent By Weight (Volatile-Free Basis)
Zinc chromate (P44-49)	21.07
Red lead (ASTM D83-41)	1.50
Red iron oxide (P42-45)	18.06
Graphitic mica (P43-47)	16.55
Crystalline silica (P33-37)	3.01
Grinding varnish (V37.25-49 non-volatile constituent)	39.81
Total non-volatile	100.00

Drier (V75) to make the paint dry to touch in not less than 4 hr. and dry hard in not more than 20 hr. Thinner not to exceed 50 per cent by weight of the total vehicle. Add 1½ lb. of lecithin as a wetting agent to each 100 gal. of the paint as made.

Zinc chromate.—The zinc chromate of the formula, of course, functions as the inhibitor of steel corrosion. It might be stated first that making all of the pigment zinc chromate, as some others have done and recommended, was tried, but it was found that paints of that kind tended to become brittle with age. A number of percentages shall use another hydrogenated petroleum naphtha (Enjay No. 3), which is somewhat slower evaporating than that used in making the paint and has a Kauri-Butanol value of not less than 68. (Mineral spirits has a Kauri-Butanol value of about 31, whereas kerosene has a Kauri-Butanol value of about 29).

Top Coats

General

Under this heading are discussed those paints which are more particularly suited to the use on steel over the previously described drying oil primers, although some of these paints used directly on metal without interposition of a primer are incidentally touched upon. It is, of course, impossible to fully cover this large subject. All that can be hoped for is to point out some of the more important factors governing their proper selection.

Top coats serve in the following capacities:

1. Simply to protect the prime coat (as, for instance, from the full effect of the oils, greases, and soaps, and from the abrasion of floating matter in a submerged location).

2. Simply to decorate the surface (as in an office or laboratory).

3. Both to protect the prime coat and to decorate the surface (as, for instance, outside in the sunlight, where the decorative coats shield the varnish of the prime coat from the effects of actinic light; also in a screen chamber, where the decorative coats protect the prime coat from the full effect of the atmospheric moisture and hydrogen sulfide).

Bituminous Coatings

Bituminous coating of various kinds have been used for ages on both iron and steel, but usually without interposition of a prime coat. In this sense, mention of a prime coat does not include the application of a clear coat of bitumen, which is sometimes used to make a heavier coat bond better to the surface. The prime coat referred to is of the nature of SDC No. 251, which is used to inhibit corrosion.)

Bituminous materials are supplied in four different forms:

1. As a hot coat material.
2. As a cutback paint.
3. As an asphaltic varnish.
4. As a water emulsion.

Hot Coats

Most engineers are familiar with the hot tar dip prescribed by the American Water Works Association for use directly on the metal of cast-iron pipe. Engineers know from experience that this coal tar dip, in most situations, provides excellent protection to the metal, especially in underground work.

In fact, it may be said generally that if a heavy hot coat of either coal tar or asphalt could be uniformly applied without pinholes or flaws and if that coating material could be designed so that it would remain intact without alligatoring, cracking, or flowing, it would provide about the best protection that could be found for under-sewage work, because these hot coat materials, although they may be somewhat softened, are not seriously affected by the oils, greases, and soaps of sewage and resist damage by floating debris very well. Unfortunately, these high ideals are not usually attainable. Coal tar tends to alligator and flow in hot weather and crack in cold weather when the water level is drawn down for some reason or other, and asphalts by nature are not entirely water- and gastight, although very thick coatings approach tightness.

When the article to be coated can be dipped in hot bitumen, as is the cast-iron pipe, or where the hot material can be spun on the interior, as is often done in a large pipe, applying it in considerable thickness, the coating can, with care, be made almost perfect, uniform, even, and free of pinholes, skips, and other flaws. However, to apply a hot coat to steel construction already erected, the hot material must be daubed onto the surface. Sanitary District experience has been that even when using experienced workmen it is very difficult to daub on a hot coat in this way without leaving pinholes and flaws, which can be detected by an electric brush drawn over the surface.

It must be remembered that hot bituminous coatings, or in fact any other type of bituminous coating, protect the steel only by being water- and gastight. If they are not water- and gastight they cannot protect, for they furnish no inhibition of corrosion such as do prime coats containing zinc or lead chromate.

It is important, therefore, that bituminous coating be quite thick and that they be applied as a solid, continuous film over the surface.

Cutbacks

From the standpoint of the protection afforded, cutbacks are by far the poorest of

the four types of bituminous coatings. Although they often display a bright and pleasing appearance, they are almost never water- and gastight.

Cutbacks have two faults. In the first place, the solvent used, particularly in the coal tar cutbacks, is very likely to lift the prime coat and thereby greatly diminish its usefulness. In the second place, cutbacks harden by evaporation of the solvents and thinners. As the volatile leaves the coating, the bitumen, which is left behind, begins to stiffen, particularly on the surface, where it forms a skin coat. The volatile then forms concentration centers, to which the remaining volatile drains to escape. These points of thinner concentration are the last places in the film to dry up. As the bitumen is freed of the volatile it shrinks, because of a reduction of volume, and as it shrinks it draws away from the centers of thinner evaporation so that in the end when the film is wholly dry these vortices remain as little wells, which do not close up because the bitumen by that time is too stiff to flow back into the holes. The film, as a consequence, remains pervious to water and gas.

Asphaltic Varnishes

Asphaltic varnishes are made by cooking gilsonite, wurtzilite, or elaterite (which are ancient solidified forms of asphalt) with tung oil or linseed oil or combinations of the two and then thinning to working consistency. They are true varnishes, for the asphalt reacts as a kind of resin to combine with the drying oil.

The varnish films, when dry, are quite waterproof, but are rather sensitive to oils, greases, and soaps. Therefore, they are not suited to under-sewage work, although they make fairly good black paints for use inside, even in rather damp locations. They are not so satisfactory for outside painting, because of the action of sunlight.

Moreover, many of the gilsonite varnishes, and perhaps some of the other types, do not keep well in the cans. The user, if he intends to store them for more than 30 days, should make sure that they will not solidify in the cans by after-polymerization.

Bituminous Emulsions

Bituminous emulsions are usually dull and uninteresting in appearance. They are, however, quite water- and gastight when dried in thick coatings. They harden by precipitation of the bitumen when the emulsion "breaks." In hardening they solidify from the bottom up, so that there is no tendency to form pinholes as is the case with cutbacks. They, therefore, present a solid, uniform, and continuous film when dry. Neither do water emulsions lift the prime coat as do some of the cutbacks, as the water is not a solvent for the primer.

In submerged conditions the Sanitary District has found use for a great deal of fibrated asphalt emulsion of the clay type as a top coat over the prime coat, but the emulsion, it has been found, must dry for at least two weeks and preferably for a month before it is submerged or it will re-emulsify.

Soap emulsions have not proved to be as good as are the clay type in submerged conditions. So-called chemical emulsions, where the emulsifying agent is made very small in percentage, are also said to be suitable for submerged conditions, but the Sanitary District has never used them.

In making the emulsion it is specified that the clear emulsion, in addition to the bitumen and the clay required for its emulsification, shall contain 10 per cent by weight zinc oxide (powdered variety is acceptable). Zinc oxide is used not only to keep the emulsion alkaline so that it does not so easily re-emulsify, but also that zinc may be present to arrest any hydrogen sulfide which may try to penetrate the film to the steel. Lime would do just as well as zinc oxide to keep the film alkaline and would be considerably cheaper, but lime does not form a stable compound with hydrogen sulfide in water so that it would not fix the H_2S as does the zinc oxide.

To this clear emulsion asbestos fiber is added in amount equal to 13 per cent of the total weight to make the asphalt cling better together when the emulsion is being applied in a heavy coat and also make it remain in place better when it is softened by the oils, greases, and soaps of sewage. Two grades of fiber are used, one-third being what is commercially known as "7-M" grade and two-thirds being what is called asbestos pulp or float.

Pigments for Decorative Paints

Before taking up decorative paints in detail, it will be well to consider first the suitability of the various pigments for use in such paints. The number of pigments that can be used for sewage works paints is rather limited because sewage gas, and especially hydrogen sulfide, reacts chemically with many of the pigments to change their color. Carbon dioxide, also a constituent of sewage gas, also reacts with some of the pigments to change their color.

From an aesthetic point of view, therefore, these effects must be carefully considered in choosing pigments for making decorative paints and that means choosing the color scheme for painting the plant with the thought in mind of the availability of suitable pigments to make the chosen colors. To cite a few instances: white lead (lead carbonate), chrome yellow (lead chromate), and chrome green (a mixture of chrome yellow and Prussian blue) are all darkened by hydrogen sulfide, which reacts to form a dirty slate-colored lead sulfide. Even lead sulfate is darkened in this way to some extent, but not to the extent of the carbonate.

Iron hydrates, such as yellow ochre and ferrite yellow, also darken with this same gas because they form ferrous sulfide. On the other hand, cadmium yellow, which is one of the best yellow pigments available, is slowly changed from yellow cadmium sulfide to white cadmium carbonate from its reaction with the carbon dioxide of sewage gas. Cadmium sulfide, therefore, tends to fade.

It is desirable, therefore, to know something about the behavior of the various pigments when they are contacted by sewage gas, or the architect will be disappointed with the result of his painting when he comes to look at the work several weeks after the painting is finished.

Although it may not be complete, the following list of pigments is believed to include all of the common color pigments that have been found satisfactory for use in decorative paints about a sewage works:

Whites—Zinc oxide, zinc sulfide, titanium dioxide, and most of the derivatives produced by "letting down" these whites by means of barytes or calcium sulfate. Antimony oxide tends to yellow a bit with hydrogen sulfide.

Blacks—So far as is known, none of the blacks are affected by sewage gas.

Oranges and yellows—Cadmium and selenium sulfides are probably the best of the orange and yellow pigments, except that the cadmium sulfide may fade a bit. Hansa yellow is stable; international orange (dinitroaniline) is also quite stable. None of the other oranges and yellows are very stable, so far as is known.

Greens—Chrome oxide green is an excellent color not affected by sewage gas. It must be distinguished from the so-called chrome greens, which are badly affected by the sewage gas. Chrome oxide in a paint applied in damp weather may display a slowing up of the drying, but when the paint finally does dry it will be found to be very hard and tough. This is because chrome oxide itself is a drier, although a rather slow-acting one. Why the drying is slowed up in damp weather the writer does not know.

Blues—There are no very good blues. The best one is probably the copper blue (phthalacyanine blue), but this blue is rather transparent. Ultramarine blue may be used in inside paints, but in sunlight a change in the crystal structure takes place, which changes the color.

Reds—Practically all iron oxide reds are stable. Toluidine red is also quite stable in mass, but tends to fade when "let down" with blanc fixe or other inert.

Browns and grays—Any derived color which can be made of any combination of the above color pigments will almost certainly be stable. Of course, dark shades of gray and brown show less darkening by hydrogen sulfide, even though some of the pigments may be affected.

Metallic Powders and Pastes

Aluminum—Turns slate-color due to formation of aluminum hydroxide, which is white, and the presence of impurities like copper, which darken it.

Zinc—Whitens, due to the formation of zinc oxide and zinc sulfide.

Bronze—Blackens, due to the formation of brown-black copper sulfide.

Chrome—Unaffected.

Pastel Shades

A word with regard to the use of pastel shades about a sewage works. Pastel shades of necessity include a considerable amount of white and the only whites which can be used are zinc oxide, zinc sulfide, antimony oxide and titanium dioxide and their let down derivatives. If the zinc or antimony oxide pigments are used in excess, there is likely to be an excessive amount of hardening, which often results in peeling of the paint or the formation of diamond or D-shaped cracks. In either case, the painting will be unsatisfactory. On the other hand, titanium dioxide pigments tend to go soft and chalk, particularly in outside paints. When a paint chalks the tint tends to fade, so that titanium paints are not generally considered to be amenable to tinting in outside paints. Inside paints, however, can be tinted.

There are two types of titanium dioxide available. Their difference is caused by differences in the crystal structure. The anatase pigment is intensely white, but is a very bad chalker. Because of its high tinting strength and its good hiding power, however, the anatase variety is generally selected for use in inside white enamels. On the other hand, the rutile variety of titanium dioxide is less strongly white, but is much less subject to chalking. It, therefore, is much better fitted to use in outside paints and to use in tinted paints. Some anatase pigment, however, is now being treated with antimony oxide to make it chalk resistant. Antimony oxide itself is too expensive to use in any great amount in the paint.

Inside and Outside Top Coats

The problem of color permanency in decorative paints has already been discussed. This particular section takes up the use of some of the inerts, and especially the types of vehicles which can be used in inside and outside paints.

Outside paints require a vehicle that will hold its elasticity over long periods of time

when exposed to sunlight and weather. The Sanitary District uses linseed oil with about 25 per cent phenolic varnish to harden the paint.

The Sanitary District found by experiment that it could have the oil treated to "M" body without causing complaint from the painters. Therefore, all the linseed oil in outside paints is made with "M" body linseed oil.

The inerts in outside paints are usually mica (usually water ground) 10 per cent, diatomaceous silica 5 per cent, and asbestine 5 per cent. Chrome oxide has been found to be an excellent color pigment for painting building trim, doors, and windows. For certain purposes, grays, based upon rutile type titanium dioxide and zinc oxide tinted with carbon black, are used.

Outside aluminum paints are also much used; made, however, entirely of a 35-gal. phenolic varnish very similar to the V37.25 varnish already described. Since the vehicle is protected from actinic light by the aluminum flakes, the elasticity of the varnish is retained in this case. The District likes aluminum paints for use on bridges, outside surfaces of steel tanks, outside handrails and valve stands, and on the exposed metal parts of mechanisms which extend above the water in concrete tanks. It is a very satisfactory outside paint, as is the chrome oxide green.

For inside paints a 35-gal. phenolic varnish is used for the entire vehicle in all paints, because the vehicle must resist moisture and acids on inside structural steel surfaces and especially on the inside surfaces of outside doors and windows. A hard paint is also needed for painting inside handrails, benches, and tables. If conditions are very bad, perhaps a 25-gal. length varnish for the vehicle would be even better for these inside paints than is the 35-gal. varnish.

In addition to mica and asbestine, a percentage of a treated calcium carbonate known commerically as "Surfex" is often used to increase the gloss of inside paints. Surfex should not be used in outside paints.

Machine Enamels

The engineer often wants his larger and more showy equipment (pumps, motors, blowers, and the like) to have a high gloss. This requires use of what is called an enamel. The principal difference between an ordinary paint and an enamel is that a paint is designed for durability and protection, whereas the enamel is designed for appearance. Usually the pigment volume is somewhat reduced in the enamel, but the same effect may be accomplished sometimes by choosing pigments that have a low oil absorption. For instance, with certain vehicles the organo-treated calcium carbonate pigment "Surfex" will add considerably to the gloss. It is necessary to keep away from asbestine and any pigment which tends to flatten the paint. Mica is a good pigment in enamels if used with discretion.

Machine enamels must be very flexible, as the machine temperature is often subject to wide swings, as between the cold end of a blower or pump in winter and the hot end of the blower in summer. They must also be resistant to the lubricating oils and greases, and particularly to the oil which a mechanic likes to use to wipe off the dust and dirt from his machine. On a steam turbine the enamel must withstand steam leakage, and perhaps a temperature up to 350° F. on uninsulated trim. It must also withstand blows from wrenches and other tools and abrasion from other equipment coming in contact.

The Sanitary District uses a 20-gal. phenolic varnish like V37.25 for the vehicle of these enamels. If, however, the enamel still does not produce the gloss which the operator thinks he ought to have, a clear coat of the same 20-gal. varnish is sometimes added over the enamel.

Vacuum Filter Drums

A problem engaging the District's attention in recent years has been the proper painting of the metal parts of the filter drums used to dewater the acidified sewage sludge. These drums revolve in the acidified sludge so that the metal parts must be kept well-painted to protect them from corrosion. However, most paints permit the sludge to adhere to the painted surface in great gobs, so that the drums come to look very unkempt. It has been found that when a vinylidene paint was used on the metal the sludge would free itself from the surface and the drums would look a lot cleaner and tidier.

Vinylidene paints are made from resin produced by the Dow Chemical Company. They must be applied to a surface that is perfectly free of all old paint, scale, and organic coatings, but the surface does not need to be sandblasted if already free of mill scale and paint. (A special solvent is used to wash the surface before painting.) A peculiarity noted of these paints is that black-colored coatings seem to adhere better to the steel than do the lighter-colored coatings. The reason for this is not known.

The Vinyl Coating System

The so-called Wash Primer Vinyl Coating System, originated and developed during World War II by the Bakelite Division of the Union Carbide and Carbon Corporation for use on ship bottoms now extensively used by the War Department on its Ohio and Mississippi River work, has been outstanding as a protective coating where the conditions are as bad as they are on the under side of the roof of an outside steel water tank and also on the metal equipment and steel construction in a screen house or a grit chamber and on the metal parts of a vacuum filter drum, it is thought that it will be helpful if this system is described in some detail. The description must, of necessity, be brief. Those who want to use the system should contact the Bakelite Corporation for full instructions and advice as to the maker.

Unsolved Problems

General

Among other things, there are three unsolved problems which have been worked on in recent months. These are:

1. A putty suitable for use on steel sash in a screen house or a grit chamber to contend with moisture, hydrogen sulfide, carbonic acid, and sulfurous and sulfuric acids. These acids tend to saturate the putty when it is used on the sash if it is not very resistant. Linseed oil putties normally used for glazing are particularly bad in that they are quickly hydrolyzed by the moisture and the acids attack the metal underneath the saturated putty pad.

2. Machine filler. A suitable machine filler is also needed. A filler is similar to a putty, but must be susceptible to being smoothed out into an even sheet from thick to thin in such a way as will fill up the irregularities in the metal. It must not crack in drying and must lend itself when dry to smoothing with sandpaper. When finished it must be hard and adherent.

It has been found that under certain conditions the machine filler will blister off from the machine surface in large sheets. This is thought to be due either to volatile from the filler being trapped before it has had time to escape from the filler when the top coats of paint are added, or else the oils which the mechanic uses to wipe off his machine in time penerate through and saturate the filler.

In either case, when the machine goes into operation and heats up, the solvent or oil is volatilized, and the gas thus formed lifts the filler and paint from the surface by forming large blisters.

3. Dust repellent coatings. At the sludge drying plant at the South West sewage treatment works there is a great deal of both organic and inorganic dust. This dust has been observed clinging to the walls and ceilings and to the metal parts of the building in great blankets. The particles appear to orient themselves in some way, for they appear to stand perpendicular to the surface like the deep pile of a carpet. Whether they are held there by a static charge, a magnetic attraction, or simply by mechanical attachment, is not known.

Aluminum-painted surfaces seem to be considerably worse at attracting the dust than is the SDC No. 251 primer. Yet experiments do not indicate that there is any great difference between paints made either with the same pigments and different vehicles or with different pigments and the same vehicle. Treatment of the surface of some of the test panels with an amine seemed to increase the amount of the coating.

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IX. ENGINEERING FUNDAMENTALS

In the design, construction, operation and management of water supply and sewage disposal systems. A knowledge of many sciences is necessary as has been indicated in the preceding sections and pages of this Reference & Data Issue. In addition to the many topics previously indicated or included in this book. There are several engineering sciences which are fundamental. These sciences are Bacteriology, Chemistry, Hydraulics and Mathematics.

Bacteriology is important not only to the laboratory technician but in water plants because the elimination of bacteria is a prime purpose of treatment. In sewage works bacteriology is important first because, bacterial actions play such an important part in the treatment, particularly in activated sludge and trickling filters and in sludge digestion and secondly because the removal of harmful bacteria is an important purpose of sewage treatment.

Chemistry is important in water treatment because chemical reactions are involved in coagulation, softening and disinfection as well as laboratory tests. In sewage treatment chemical reactions take place in secondary treatment, sludge digestion, disinfection and stream pollution.

Hydraulics and the principles on hydraulic engineering are fundamental to the concept and control of the flow of fluids. Thus the pumping of water and sewage or gas or its free flow, and its measurement in flow are all a part of this basic engineering subject.

Mathematic is the basis of all engineering relationships. Mathematical equations, systems and functions are essential to the determination, recording or calculation of data on processes, actions and results of water and waste-water handling and treatment.

Over the years, men working in the field of sanitary engineering have developed tables, charts, diagrams, graphs, nomograms and other tools of mathematics to simplify and speed the applications of these fundamentals sciences to the problems of operation of water and sewage works. The following pages contain some of these short-cut operating tools.

Loss of Head in Pipes and Fittings

THERE are numerous times when a water works engineer wishes to know the loss in head in some particular line. Information on this subject is not lacking but often is scattered in various texts and magazines. Diagrammatic charts, prepared by the application of the Hazen-Williams, and Scobey formulas for flow of water in pipes have been developed as aids to the solution of problems involving loss of head. Tables and charts of loss of head through valves and fittings are likewise available from various sources and authors.

In an attempt to bring these data tables, charts, and diagrams together in one place the following collection is presented. Together with such running comment as is necessary, the information in the following pages should be sufficient to solve any problem in loss of head.

Flow of Water in Pipe[1]

The carrying capacity of a pipe line may be regarded as the index of its hydraulic efficiency. Selection of the most suitable hydraulic characteristics to satisfy the economics of a given installation usually involves consideration of several alternate procedures, and comparisons of their respective characteristics, before the most appropriate choice can be made. These comparisons can only be as valid as the underlying hydraulic assumptions they depend on, hence the importance of suitable expressions correctly formulating the proper relationships involved.

Many studies have been made to determine these relationships, and many formulae developed to express them. In 1775, Chezy, a French engineer, offered his well-known formula for the flow of water in open channels and closed conduits:

$$V = C\sqrt{r\,s},$$

"C" being a coefficient at first supposed to have a constant value, but now known to vary with the velocity, slope, hydraulic radius, and with some factor representing influences of contact surfaces. The Kutter elaboration of the Chezy formula reads:

$$V = \left(\frac{\frac{1.811}{n} + \frac{0.00281}{s} + 41.66}{1 + \frac{n}{\sqrt{r}}\left[41.66 + \frac{0.00281}{s}\right]} \right) \sqrt{r\,s},$$

in which "C" of the Chezy formula has been developed into the bracketed expression shown at left, which also introduces a new variable "n", supposed to represent all retarding influences. Unfortunately, however, the value of "n" varies somewhat for pipe, both with size and velocity. Now if we examine for a moment the basic formula

$$h_f = \frac{f\,L\,V^2}{2gd}$$

which can be established by the usual hydraulic reasoning, we find the Chezy formula recognizable in it, and also the well-known formulas of Darcy Weisbach and Fanning. All these suffer in a basic respect, in that the friction "constant" does not remain constant throughout the range of application. In the early 1900's these discrepancies began to create a definite reaction against the use of the basic simple assumption that $V = C\sqrt{r\,s}$*, culminating in the presentation of the Williams-Hazen formula. In other words, more critical scrutiny and application of available data indicated that the loss of head does not vary as the square of the velocity, but in accordance with a value lying somewhere between 1.70 and 2.00. It is now fairly well understood that theirs (i.e., the exponential type of formula) is preferable to any other form; also that losses within most closed conduits at velocities within the range of ordinary extremes of service require what Scobey calls "a compromise value somewhat less than 2.00".

The Williams-Hazen formula is now widely accepted, and reads:

$$V = C\,r^{0.63}\,S^{0.54}\,.001^{-0.04},$$ where

V = mean velocity of flow, in feet per second.
C = "coefficient of retardation," so-called.
r = mean hydraulic radius of the pipe, or diameter D ÷ 4, in feet.
s = hydraulic grade or slope, in feet per foot of length of a pipe of uniform size.

or

$$S^{0.54} = \frac{V}{C\left[\frac{D}{4}\right]^{0.63} \times 0.001^{-0.04}}$$

$$= \frac{4^{0.63}\,V}{1.318\,C\,D^{0.63}}$$

$$S = \frac{4^{1.587}\,V^{1.852}}{1.318^{1.852}\,C^{1.852}\,D^{1.167}}$$

$$= \frac{3.0236\,V^{1.852}}{C^{1.852}\,D^{1.167}}$$

$$S_{1000}\left[\begin{matrix}\text{Loss of Head}\\ \text{in Feet, per}\\ \text{1,000 Feet}\end{matrix}\right] = \frac{3023.6\,V^{1.852}}{C^{1.852}\,D^{1.167}}$$

$$= K\frac{V^{1.852}}{D^{1.167}}$$

when $\begin{cases} C = & 90 & 95 & 100 & 105 & 110 & 115 \\ K = & .727 & .657 & .598 & .546 & .501 & .461 \end{cases}$

or $\begin{cases} C = & 120 & 125 & 130 & 135 & 140 \\ K = & .426 & .395 & .367 & .343 & .321 \end{cases}$

Loss of Head Charts Based on the Hazen-Williams and Scobey Formulas

In the following pages appear four charts (Fig. 1, 2, 3, 4) for determining loss of head in lineal pipe lines. The first three were developed from the Hazen-Williams Formula and apply to any pipe. The last was developed from the Scobey formula and is applicable to concrete pipes.

Figure 1 was prepared by William P. Creager,[3] Chief Engineer, The Power Corporation of New York, and was originally published by John Wiley and Sons in the Hydro-Electric Handbook, by Creager and Justin.

Figures 2 and 3 are nomographs and were prepared for an article on the Hardy Cross Method by D. R. Taylor [3]. Figure 4, also a nomograph, was prepared by J. R. Griffiths, of the U. S. Navy[4].

Values of the Coefficient "C"

Although the second and third charts are for definite values of the friction coefficient "C" in the Hazen-Williams Formula, the first chart by Creager may be used for any value of "C," if that value is known.

Recommended values of "C" for the Hazen-Williams Formula were given by Hazen and Williams in their book, "Hydraulic Tables"[2]. These values for straight line conduits are shown in Table 1.

TABLE 1

Table of C Values Cast Iron Pipe

Diameter Inches	Age in Years* 0	5	10	20	30	40	50
4	130	118	107	89	75	64	55
8	130	119	109	93	83	73	65
12	130	120	111	96	86	77	70
16	130	120	112	98	87	80	72
24	130	120	113	100	89	81	74
30	130	120	113	100	90	83	76
36	130	120	113	100	90	83	76
40	130	120	113	100	90	83	77
60	130	120	113	100	90	83	77

*Cleaning old pipe increases the C value.

Riveted Steel Pipe
  Light riveted steel pipe—
    Avg. C for any age = 10 year C.I.P.
  Heavy riveted steel pipe—
    Avg. C for any age = 20 year C.I.P.
Welded Steel Pipe
  Equivalent to 5 yr. or older C.I.P.
Wood Stave Pipe
  Best C = 145
  Probable Average C = 120
  Worst C = 110
Concrete Pipes and Pressure Tunnels
  Metal Forms
    Best workmanship— C = 150
    Probable workmanship—C = 140
    Worst workmanship— C = 120
  Wood Form—Monolithic
    Best workmanship— C = 130
    Probable workmanship—C = 120
    Worst workmanship— C = 90
  If Slimed
    20 points below Best
    15 points below Average
    10 points below Worst

In addition to the values in Table 1 the following values of the friction coefficient have been published by the National Tube Co.[5]

These values of the coefficient "C" are to be used in the Hazen-Williams formula for computing the loss of head due to friction in new well-laid pipe:

Kind of Pipe	Coefficient
"Duroline"	148*†
Wrought Steel	140
Small Brass and Copper	130
Cast Iron	130
Concrete	120
Wood Stave	120
Riveted Steel	110
Vitrified Pipe	110
Brick Sewers	100

*"Duroline" pipe is protected against internal corrosion and mounting friction losses by a cement base composition lining of a highly durable nature.—Ed.

†Approximately the same for cement lined pipe. —Ed.

It must be understood that these values depend upon the smoothness and regularity of the surfaces and are likely to vary in individual cases. In designing a pipe line it is customary to use somewhat lower coefficients than those above, to allow for variations due to local conditions, and for reduction of carrying capacity with age due to roughening of the inside surface, accumulation of corrosion products, and tuberculation. However, in case of cement or enamel lined pipe, the volume of flow remains practically unchanged over long periods of service due to the fact that rust tubercles do not form and the initially smooth inside surface is retained.

Useful Loss of Head Tables

D. R. Taylor[3] gives two tables on loss of head. The first (Table 2) gives values for use in the formula

*Convertible into the general formula $H = \frac{V_x}{D^y}$; when H = 1000s, x = 2, and y = 1.

$$S = R Q_m^{1.85}$$

where S = loss of head per 1000 ft.
R = resistance factor depending on size and smoothness of pipe.
Q_m = quantity of flow in gal. per min.

Values in the table are given as "k" values which are equal to 100,000 times the "R" value.

Table 3 gives "R" values when the flow quantity is expressed in mil. gal. per day, for the formula $S = RQ_s^{1.85}$

where S = loss of head per 100 ft. of pipe.
R = resistance factor.
Q_s = quantity flow in mgd.

In Table 4 are listed pipe friction for various size pipes and velocities.[6]

Loss of Head for Valves and Fittings

The following discussion and its accompanying chart titled Friction Chart for Valves and Fittings have been taken from Crane Company's "Engineering Data on Flow of Fluids in Pipes[7]"

When the flow of a fluid in a pipe line is altered by some obstruction such as a valve or fitting, the velocity is changed, turbulence is magnified and a drop in pressure results. This pressure drop may be insignificant in long lines where it is very small in comparison to the total drop, but when the line is short the pressure drop through valves

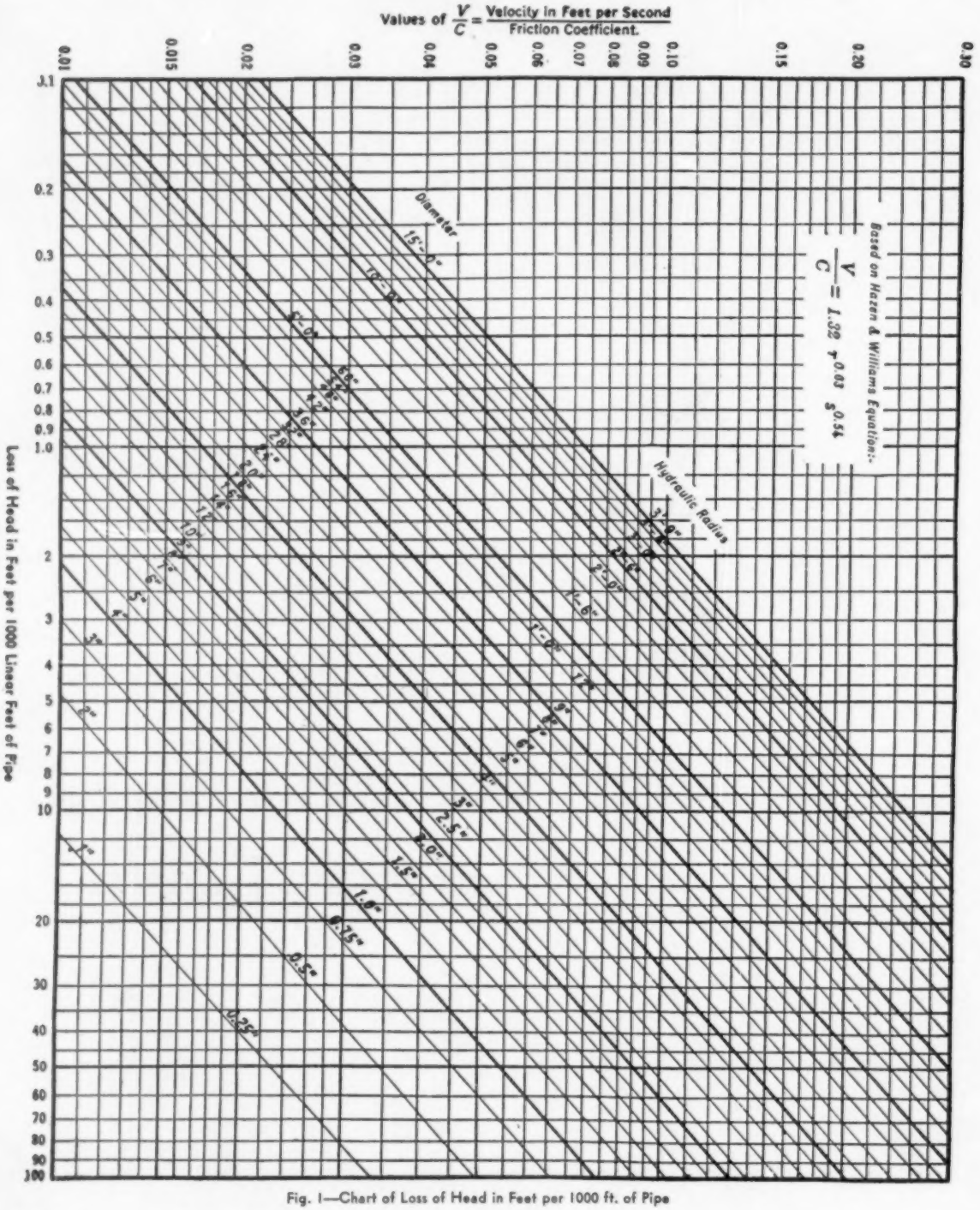
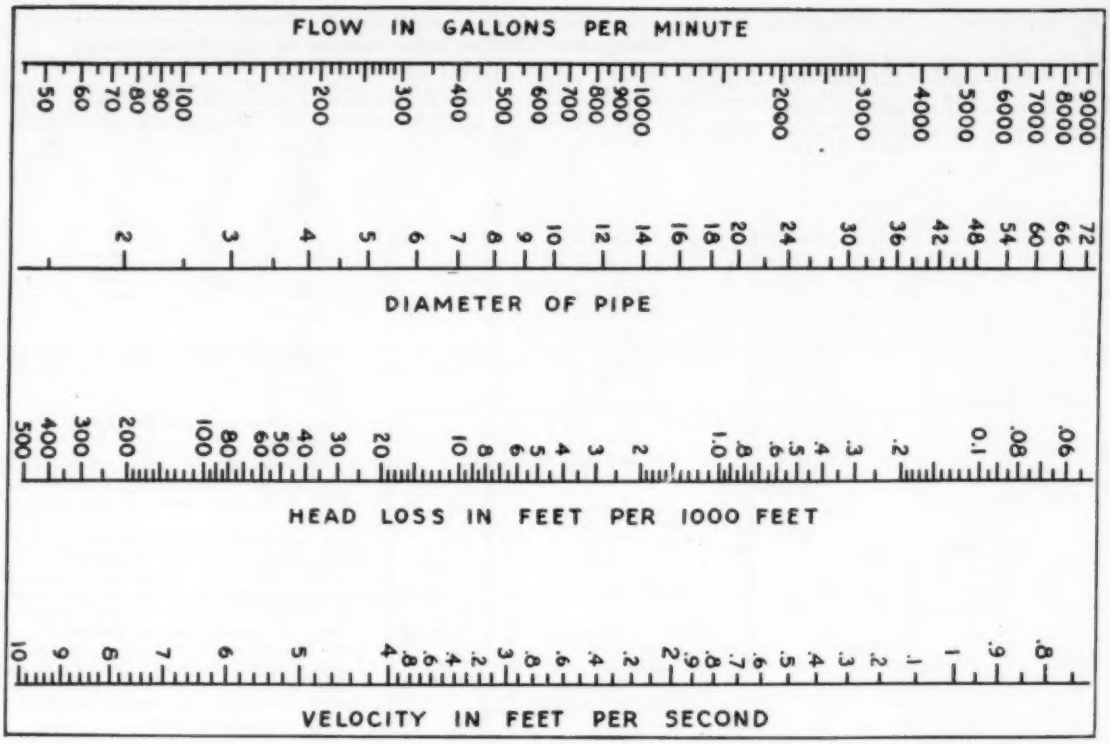
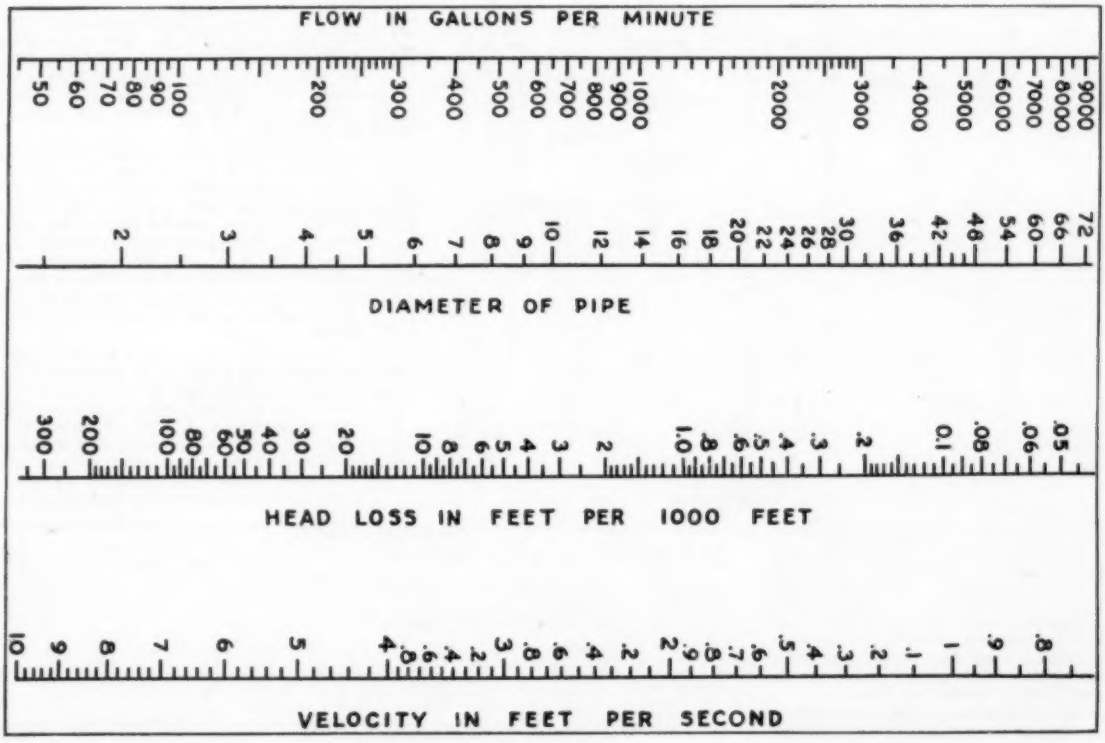


Fig. 1—Chart of Loss of Head in Feet per 1000 ft. of Pipe


FLOW IN GALLONS PER MINUTE
50 60 70 80 90 100 200 300 400 500 600 700 800 900 1000 2000 3000 4000 5000 6000 7000 8000 9000
2 3 4 5 6 7 8 9 10 12 14 16 18 20 24 30 36 42 48 54 60 66 72
DIAMETER OF PIPE
500 400 300 200 100 80 60 50 40 30 20 10 8 6 5 4 3 2 1.0 .8 .6 .5 .4 .3 .2 0.1 .08 .06
HEAD LOSS IN FEET PER 1000 FEET
10 9 8 7 6 5 4 .8 .6 .4 .2 3 .8 .6 .4 .2 2 .9 .8 .7 .6 .5 .4 .3 .2 1 1 .9 .8
VELOCITY IN FEET PER SECOND


FLOW IN GALLONS PER MINUTE
50 60 70 80 90 100 200 300 400 500 600 700 800 900 1000 2000 3000 4000 5000 6000 7000 8000 9000
2 3 4 5 6 7 8 9 10 12 14 16 18 20 22 24 26 28 30 36 42 48 54 60 66 72
DIAMETER OF PIPE
300 200 100 80 60 50 40 30 20 10 8 6 5 4 3 2 1.0 .8 .6 .5 .4 .3 .2 0.1 .08 .06 .05
HEAD LOSS IN FEET PER 1000 FEET
10 9 8 7 6 5 4 .8 .6 .4 .2 3 .8 .6 .4 .2 2 .9 .8 .7 .6 .5 .4 .3 .2 1 1 .9 .8
VELOCITY IN FEET PER SECOND

and fittings becomes a major item in the total pressure drop valve.

The most widely used data on the subject of the resistance of valves and fittings to the flow of water and steam is the information given in Dean Foster's paper on "Effect of Fittings on Flow of Fluids Through Pipe Lines."[8] Tests conducted by others have indicated that the values given by Foster are low for globe valves, angle valves, etc., and that data is needed to establish the correct information to use. It has been the tendency, and probably is the most practical way, to present the friction values in terms of an equivalent length of the same size of pipe; i.e., the pressure drop caused by a 2-inch elbow is equivalent to approximately the pressure drop caused by five or six feet of 2-inch pipe under the same conditions of flow.

TABLE 2

Values of k for 1,000 Feet of Pipe Based on the Hazen-Williams Formula

Pipe Diameter, Inches	C= 90	100	110	120	130	140
4	300	248	208	117	153	133
6	41	33.7	28.4	24.2	20.9	18.2
8	10	8.4	7.0	6.0	5.2	4.5
10	3.4	2.8	2.4	2.0	1.7	1.5
12	1.5	1.2	1.0	.83	.71	.62
14	.66	.55	.46	.39	.34	.30
16	.35	.29	.24	.20	.18	.15
18	.20	.16	.14	.12	.10	.09
20	.12	.10	.08	.07	.06	.05
24	.049	.04	.03	.03	.02	.02
30	.016	.013	.011	.010	.008	.007
36	.0067	.0054	.0046	.0039	.0034	.0030

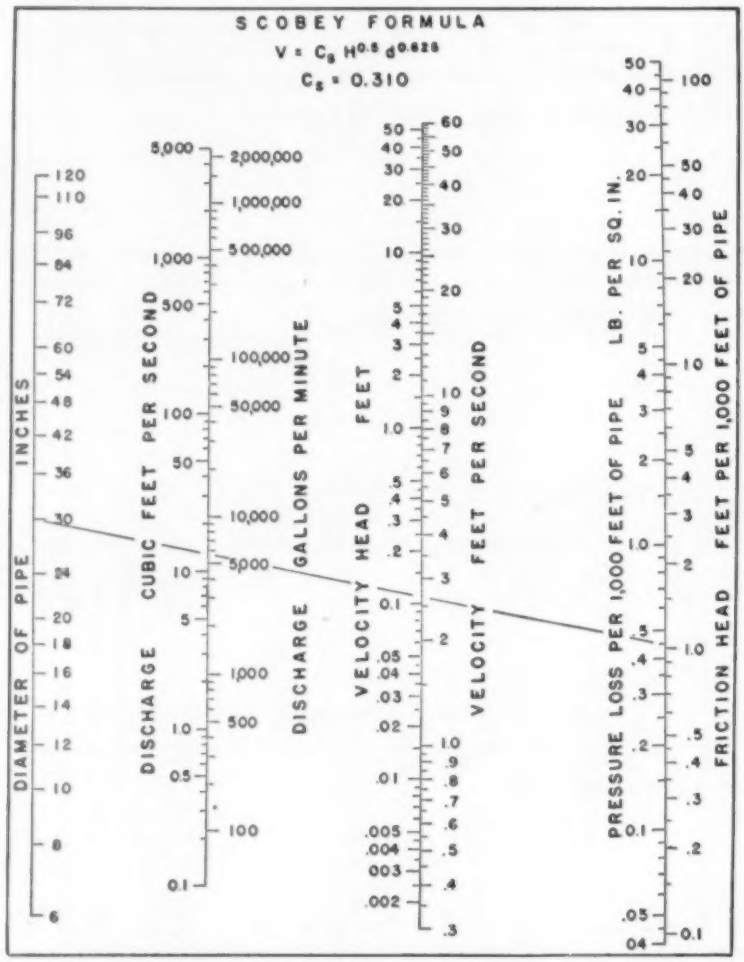

SCOBEY FORMULA
V = C_s H^0.5 d^0.625
C_s = 0.310
DIAMETER OF PIPE INCHES
DISCHARGE CUBIC FEET PER SECOND
DISCHARGE GALLONS PER MINUTE
VELOCITY HEAD FEET
VELOCITY FEET PER SECOND
PRESSURE LOSS PER 1,000 FEET OF PIPE LB. PER SQ. IN.
FRICTION HEAD FEET PER 1,000 FEET OF PIPE

Fig. 4—Flow of Water in Concrete Pipe

Realizing the need for definite data covering this subject, Crane Co. conducted pressure drop tests on valves and fittings on both water and steam. These tests were made on 2 inch and 6 inch sizes and conducted under conditions which were thoroughly investigated previous to the tests. The results of these tests are presented herewith together with a description of the method used in conducting them.

[*Note.*—Water and steam can be treated comparatively and a relation can be established between the relative friction values of water and steam. Foster has stated that the equivalent length of pipe for steam flow is about .8 of that established for the flow of water.]

Friction Losses of Water Line Valves and Fittings

The tests for determining the pressure drop of valves and fittings installed in a water line were made in the following manner:

A flow nozzle was installed in a 3 in. test line leading from the bottom of a 1,000 gallon water tank. A mercury manometer was set across this nozzle and the relation of mercury deflection to the gallons of water per minute flowing through the pipe was determined. The flow through the pipe was thereafter noted only in terms of mercury deflection which was readily transposed into gallons per minute by reference to the calibration chart.

The valve or fitting to be tested was placed in the line at some distance from the flow nozzle and the flow water through it was regulated by a throttling valve situated at the outlet of the line. The pressure drop was measured by means of a mercury manometer, or where the deflection was too great, by two sensitive low pressure gages, the leads of which were situated in the test line at a distance of ten pipe diameters (20 in.) from each end of the valve or fitting on test. The initial pressure at the inlet of the test line was kept constant at 80 pounds per square inch and the various rates of flow were produced by throttling the outlet of the test line.

After the data was obtained the means of presenting it in its best form was investigated. In any pressure drop tabulation, the values for the fittings and valves in the line are added to the pressure drop of the entire length of line. Therefore, it seemed reasonable to disregard the pressure drop caused by the length of the valve or fitting and just list the pressure drop which was added to the line due to the presence of the article.

For instance, if a valve 4 in. face to face is installed in a line 30 in. long, the actual pressure drop through the valve will be the total pressure drop minus the pressure drop caused by 26 in. of pipe. However, in a practical problem this value will be added to the pressure drop caused by the total length of the line which will give a pressure drop value slightly higher than the actual.

Age Factors For Fig. 5

	Age in Years						
	New	10	15	20	30	50	75
Fire Protection Mains—No Domestic Draft	0.7	0.9	1.0	1.1	1.4	1.8	2.3
Public and Fire Protection Mains with Domestic Draft							
Surface Water							
Slight Tuberculation	0.7	0.9	1.0	1.1	1.4	1.8	2.3
Moderate Tuberculation	0.7	1.2	1.7	2.1	2.9	3.5	3.9
Severe Tuberculation	0.7	1.6	2.4	3.1	4.5	5.2	5.5
Well Water	0.7	1.6	2.4	3.1	4.5	5.2	5.5

These age factors for cast-iron mains are adapted from the results of an investigation by a committee of the New England Water Works Association[18].

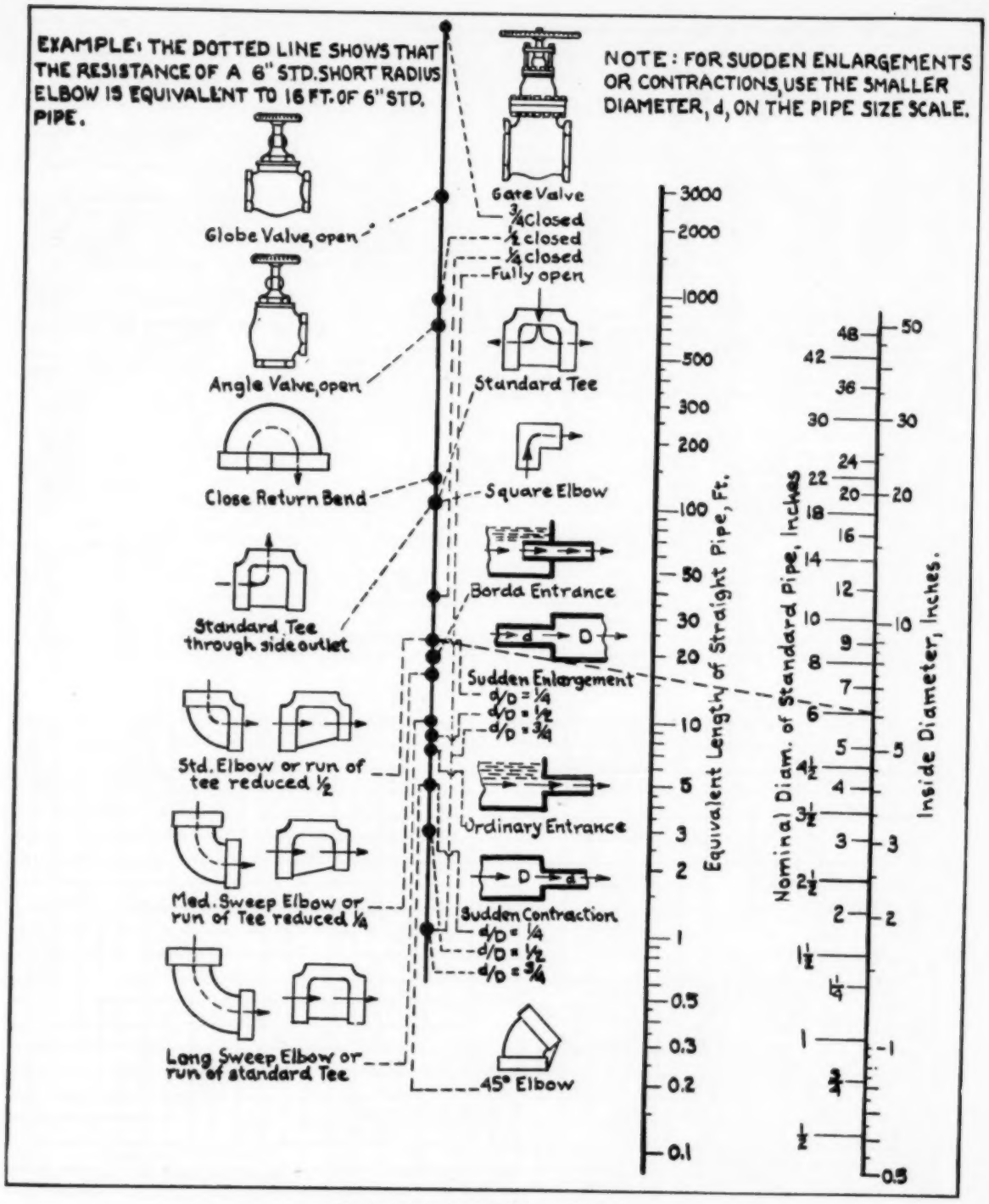


Fig. 5—Friction Chart for Valves and Fittings
(For Converting These Units Into Equivalent Added Length of Pipe)*

*Note: These equivalents, in terms of length of pipe to be added in computations, were derived for steel pipe in good condition. In applying the chart to cast-iron pipe divide the equivalent length of steel pipe by 1.64 times the most appropriate age factor found in Table 5 of "Age Factors" for C.I. mains.

TABLE 3

Values of "R" for 1,000 Ft. of Pipe Based on Hazen and Williams Formula

d—Inches	Head Loss in Ft.: S = R x $Q^{1.85}$ per 1,000 ft. (Q in m.g.d.)							
	c = 70	c = 80	c = 90	c = 100	c = 110	c = 120	c = 130	c = 140
4	860.69	672.31	540.67	444.91	373.00	317.53	273.83	238.76
6	119.44	93.30	75.03	61.74	51.76	44.06	38.00	33.13
8	29.42	22.98	18.48	15.21	12.75	10.85	9.36	8.16
10	9.93	7.75	6.24	5.13	4.30	3.66	3.16	2.75
12	4.08	3.19	2.57	2.11	1.77	1.51	1.30	1.13
14	1.925	1.504	1.209	0.995	0.834	0.710	0.612	0.534
16	1.007	0.787	0.633	0.521	0.437	0.372	0.320	0.279
18	0.567	0.443	0.356	0.293	0.246	0.209	0.180	0.157
20	0.3390	0.2648	0.2130	0.1753	0.1469	0.1251	0.1079	0.0941
24	0.1396	0.1091	0.0877	0.0722	0.0605	0.0515	0.0444	0.0378
30	0.0471	0.0368	0.0296	0.0244	0.0204	0.0174	0.0150	0.0151
36	0.01939	0.01514	0.01218	0.01002	0.00840	0.00715	0.00617	0.00528
42	0.00915	0.00715	0.00575	0.00473	0.00397	0.00338	0.00291	0.00254
48	0.004774	0.003729	0.002999	0.002468	0.002057	0.001761	0.001519	0.001324
60	0.001611	0.001258	0.001012	0.000833	0.000698	0.000594	0.000513	0.000447
66	0.001013	0.000791	0.000636	0.000524	0.000439	0.000374	0.000322	0.000281

This may not be so noticeable with one or two valves or fittings in the line, but where the number runs up into 10 or 20 the added drop may be considerable.

This "No-length" concept was established and has been used before with reference to elbows by F. E. Giesecke.[6]

Resistance in Terms of Equivalent Pipe Length

From data given in the tests conducted by Crane Co. and also from information gathered from authentic sources, the friction chart for valves and fittings, shown in Fig. 5, has been prepared which gives the equivalent length of pipe to produce the same pressure drop as a valve or fitting. This additional pipe length should be added to the length of the line in order to determine the total pressure drop.

In using Fig. 5, it must be remembered that the values were derived for steel pipe in good condition. In applying the chart to cast iron pipe divide the equivalent length of steel by 1.64 times the appropriate age factor in the table opposite Fig. 5.

The equivalent length of pipe has been based upon the pressure drop values for the flow of water in pipes and upon the coefficients of the formula.

$$H_1 = K\frac{V^2}{2g}$$

where H_1 = Loss of head in ft.
K = Coefficient
V = Velocity in ft. per sec.
$2g$ = 64.4

Coefficients for use in this formula are shown in Table 5.

Burns and McDonnell, Engineers, prepared the chart (Fig. 6) by which the loss in head in fittings and valves may be determined.

In Fig. 6, to determine loss of head—assume flow (Q) to be 5 ft. per sec. through a fitting of 12 in. diameter. From $Q = AV$, the velocity $(V) = 6.4$ ft. per sec. From the chart, velocity head $\frac{V^2}{2g} = 0.7$ ft.

Applied to 90 degree bend head loss is $0.25 \times 0.7 = 0.18$ ft. For a tee $1.25 \times .7 = 0.87$ ft.

(Note—Correspondence with the producers of this chart cites values for check valves far in excess of the 0.5 indicated.—*Ed.*)

Another method of determining loss of head in fittings and valves is given in Table 6 with approximate head losses for various fittings. Exact losses cannot be determined due to variation in construction details.

TABLE 5

Loss of Head Coefficients for Fittings and Valves

Type	Coefficient	Authority
Globe Valves	10	Ref. No. 7
Angle Valve	5	Ref. No. 7
Return Bend	2.2	
Tee	1.8	Ref. No. 9
Short Radius Elbow	.9	Ref. No. 9
Med. Radius Elbow	.75	Ref. No. 7
Long Radius Elbow	.60	Ref. No. 10
Gate Valve (Open)	.19	Av. Ref. No. 11
¼ Closed	1.15	Av. Ref. No. 11
½ Closed	5.6	Av. Ref. No. 11
¾ Closed	24.0	Av. Ref. No. 11
Borda Entrance	.83	Av. Ref. No. 12
Sudden Enlargement		
d/D — ¼	.92	Ref. No. 12
d/D — ½	.56	Ref. No. 12
d/D — ¾	.19	Ref. No. 12
Ordinary Entrance	.5	Ref. No. 12
Sudden Contraction		
d/D = ¼	.42	Ref. No. 12
d/D = ½	.33	Ref. No. 12
d/D = ¾	.19	Ref. No. 12
45° Elbow	.42	Ref. No. 10

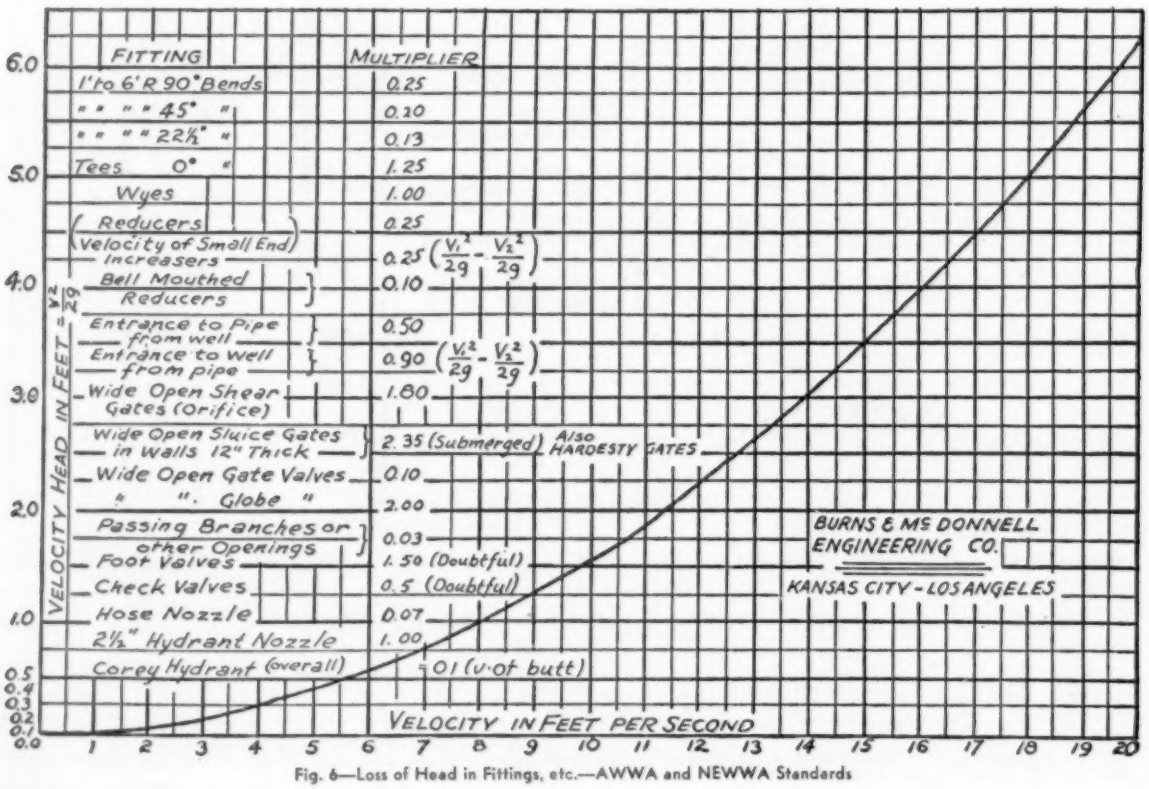


Fig. 6—Loss of Head in Fittings, etc.—AWWA and NEWWA Standards

TABLE 4

Friction of Water in Pipes

The pipe frictions shown in the following tables are taken by permission from the more complete copyright tables by Williams and Hazen, published by John Wiley & Sons, and these values are recommended for use in figuring pipe frictions.

Loss of Head in Feet Due to Friction, per 100 feet of 15 year old Ordinary Iron Pipe

U.S. Gal's per Min.	1" Pipe		1¼" Pipe		1½" Pipe		2" Pipe		2½" Pipe		3" Pipe	
	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.
10	3.72	11.7	2.14	3.05	1.57	1.43	1.02	0.50	0.65	0.17	0.45	0.07
15	5.60	25.0	3.2	6.50	2.36	3.0	1.53	1.0	0.98	0.36	0.68	0.15
20	7.44	42.0	4.29	11.1	3.15	5.2	2.04	1.82	1.31	0.61	0.91	0.25
25	9.30	64.0	5.36	16.6	3.94	7.8	2.55	2.73	1.63	0.92	1.13	0.38
30	11.15	89.0	6.43	23.5	4.72	11.0	3.06	3.84	1.96	1.29	1.36	0.54
35	13.02	119.0	7.51	31.2	5.51	14.7	3.57	5.1	2.29	1.72	1.59	0.71
40	14.88	152.0	8.58	40.0	6.3	18.8	4.08	6.6	2.61	2.20	1.82	0.91
45			9.65	50	7.08	23.2	4.60	8.2	2.94	2.80	2.05	1.15
50			10.72	60	7.87	28.4	5.11	9.9	3.27	3.32	2.27	1.38
70			15.01	113	11.02	53.0	7.15	18.4	4.58	6.2	3.18	2.57
90					14.17	84.0	9.19	29.4	5.88	9.8	4.09	4.08
100					15.74	102.0	10.21	35.8	6.54	12.0	4.54	4.96
120					18.89	143.0	12.25	50.0	7.84	16.8	5.45	7.0
140					22.04	190.0	14.30	67.0	9.15	22.3	6.35	9.2
160							16.34	86.0	10.46	29.0	7.26	11.8
180							18.38	107.0	11.76	35.7	8.17	14.8
200							20.42	129.0	13.07	43.1	9.08	17.8
220							22.47	154.0	14.38	52.0	9.99	21.3
240							24.51	182.0	15.69	61.0	10.89	25.1
260							26.55	211.0	16.99	70.0	11.80	29.1
280									18.30	81.0	12.71	33.4
300									19.61	92.0	13.62	38.0

U. S. Gal's per Min.	4" Pipe		5" Pipe		6" Pipe		8" Pipe		10" Pipe		12" Pipe		14" Pipe		15" Pipe		16" Pipe		20" Pipe		24" Pipe	
	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.
40	1.02	0.22																				
45	1.17	0.28																				
50	1.28	0.34																				
70	1.79	0.63	1.14	0.21																		
75	1.92	0.73	1.22	0.24																		
100	2.55	1.22	1.63	0.41	1.14	0.14																
120	3.06	1.71	1.96	0.58	1.42	0.25																
125	3.19	1.86	2.04	0.64	1.48	0.28																
150	3.84	2.55	2.45	0.88	1.71	0.32																
175	4.45	3.44	2.86	1.18	2.00	0.48																
200	5.11	4.40	3.27	1.48	2.28	0.62																
225	5.77	5.45	3.67	1.86	2.57	0.74																
250	6.40	6.72	4.08	2.24	2.80	0.92	1.60	0.22														
270	6.90	7.70	4.42	2.60	3.03	1.13	1.70	0.25														
275	7.03	7.99	4.50	2.72	3.06	1.15	1.73	0.27														
300	7.66	9.30	4.90	3.14	3.40	1.29	1.90	0.32														
350	8.90	12.32	5.72	4.19	3.98	1.75	2.20	0.42														
400	10.21	16.00	6.54	5.40	4.54	2.21	2.60	0.54														
450	11.50	19.80	7.35	6.70	5.12	2.65	2.92	0.68	1.80	0.21												
470	12.10	22.40	7.70	7.22	5.49	2.90	3.07	0.75	1.92	0.24												
475	12.20	22.96	7.76	7.42	5.55	2.95	3.10	0.76	1.94	0.25												
500	12.77	24.00	8.17	8.12	5.60	3.30	3.20	0.82	2.04	0.28	1.42	0.11										
550			8.99	9.60	6.16	3.93	3.52	0.97	2.25	0.33	1.57	0.14										
600			9.80	11.30	6.72	4.70	3.84	1.14	2.46	0.39	1.71	0.15										
650			10.62	13.20	7.28	5.40	4.16	1.34	2.66	0.46	1.85	0.19	1.37	0.09								
700			11.44	15.10	7.84	6.20	4.46	1.54	2.86	0.52	2.00	0.22	1.47	0.10								
750			12.26	17.20	8.50	7.00	4.80	1.74	3.06	0.59	2.13	0.24	1.58	0.11								
800					9.08	8.00	5.12	1.97	3.28	0.67	2.27	0.27	1.68	0.13								
850					9.58	8.95	5.48	2.28	3.48	0.75	2.41	0.31	1.79	0.14								
900					10.30	10.11	5.75	2.46	3.68	0.83	2.56	0.34	1.89	0.16								
950					10.72	10.80	6.06	2.87	3.88	0.91	2.70	0.38	2.00	0.18	1.73	0.12						
1000					11.32	12.04	6.40	3.02	4.08	1.01	2.84	0.41	2.10	0.19	1.82	0.14						
1050					11.90	13.30	6.70	3.21	4.29	1.09	2.98	0.44	2.20	0.22	1.91	0.16						
1100					12.50	14.31	7.03	3.51	4.50	1.20	3.13	0.49	2.31	0.23	2.00	0.17						
1150					12.95	15.60	7.35	3.84	4.71	1.34	3.27	0.53	2.42	0.25	2.09	0.18						
1200					13.52	16.69	7.67	4.15	4.91	1.46	3.41	0.57	2.52	0.26	2.18	0.19						
1250					14.10	18.50	8.00	4.45	5.11	1.51	3.55	0.62	2.63	0.29	2.28	0.20	1.99	0.15				
1500							9.60	6.27	6.10	2.09	4.20	0.85	3.15	0.39	2.73	0.28	2.39	0.21				
2000							12.70	10.71	8.10	3.65	5.60	1.43	4.20	0.66	3.64	0.54	3.19	0.39			1.42	0.05
2500									10.10	5.33	7.00	2.28	5.25	1.01	4.55	0.72	3.99	0.56			1.77	0.07
3000									12.10	7.80	8.40	3.15	6.30	1.47	5.46	1.12	4.79	0.80	3.08	0.27	2.13	0.10
3500									14.10	10.08	9.80	4.10	7.35	1.81	6.37	1.43	5.59	1.04	3.59	0.35	2.49	0.14
4000											11.35	5.32	8.40	2.47	7.28	1.85	6.38	1.34	4.10	0.45	2.85	0.18
4200											11.93	6.00	8.82	2.80	7.64	2.08	6.72	1.45	4.32	0.50		
4500											12.78	6.90	9.45	3.22	8.19	2.23	7.20	1.65	4.62	0.56	3.20	0.22
5000											14.20	8.40	10.50	3.92	9.10	2.78	7.96	2.02	5.13	0.68	3.54	0.27
5500													11.55	4.65	10.01	3.30	8.78	2.39	5.64	0.82	3.90	0.33
6000													12.60	5.50	10.92	3.90	9.56	2.60	6.15	0.96	4.25	0.38
6500													13.65	6.45	11.83	4.55	10.36	3.32	6.66	1.06	4.61	0.45
7000													14.70	7.15	12.74	5.08	11.12	3.68	7.18	1.28	4.97	0.52
7200															13.10	5.45	11.50	3.96	7.38	1.35		
7500															13.65	5.90	11.95	4.28	7.66	1.45	5.32	0.59
8000																			8.17	1.63	5.68	0.66
8500																			8.68	1.83	6.03	0.74
9000																			9.20	2.04	6.35	0.81
9500																			9.70	2.23	6.74	0.91
10000																			10.40	2.53	7.07	0.98

Vel.—Velocity ft. per second. Fric.—Friction head in feet.

TABLE 7

Values for Determining Head Losses for Fittings

Diameter of fittings	1	1¼	2	2½	3	4	5	6	7	Inches
Constant	2.5	3.75	5	6.25	7.5	10	12.5	15	17.5	Constant
	8	9	10	11	12	15	16	18	20	Inches
	20	22.5	25	27.5	30	37.5	40	45	50	Constant

Multipliers for Different Fittings

45° Ell	0.26	*Angle Globe Valve	5.0	Reciprocating piston	20.0
90° Ell	1.0	*Check Valve	3.0	Turbine wheel type (Double flow balanced)	8.3
Tee	2.0	Water Meters:		Venturi Meters:	
*Gate Valve	0.37	Disk or wobble plate type	9.0	Ratio of $d_2/d_1 = 0.5$	2.66
*Globe Valve	3.33	Rotary (disk or star shape, as piston)	13.3	Ratio of $d_2/d_1 = 0.4$	5.66

*Multipliers are for valves operating wide open.

In Table 6 under each size fitting is a constant which, multiplied by the multiplier for each kind of fitting in the pipe line, will give the additional length in feet to be added to the actual length of discharge pipe or pipe line. Take, for example, a 10-inch pipe line 300-feet long with 2-90° ells, 1-gate valve, 1-check valve and a venturi meter having a ratio of $d_2/d_1 = 0.5$. The additional length for head loss in these fittings is made up as follows: 2-90° ells 25-feet each, 1-gate valve 9-feet, 1-check valve 75-feet, 1-venturi meter 66-feet, making a total of 200-feet additional which must be added to the 300-feet actual length, or the equivalent of 500-feet of new 10-inch pipe line upon which the friction head loss must be figured in order to arrive at the total loss in the pipe line and fittings.

References

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Equation of Pipes

It is frequently desired to know what number of pipes of a given size are equal in carrying capacity to one pipe of a larger size. At the same velocity of flow the volume delivered by two pipes of different sizes is proportional to the squares of their diameters; thus one 4-inch pipe will deliver the same volume as four 2-inch pipes. With the same head, however, the velocity is less in the smaller pipe, and the volume delivered varies about as the square root of the fifth power. This table is calculated on this basis. The figures opposite the intersection of any two sizes is the number of the smaller-sized pipes required to equal one of the larger; thus one 4-inch equals 5.7 two-inch.

Dia. in.	1	2	3	4	5	6	7	8	10	12	14	16	18	20	24	30	36
2	5.7	1.															
3	15.6	2.8	1.														
4	32.	5.7	2.1	1.													
5	55.9	9.9	3.6	1.7	1.												
6	88.2	15.6	5.7	2.8	1.6	1.											
7	130.	22.9	8.3	4.1	2.3	1.5	1.										
8	181.	32.	11.7	5.7	3.2	2.1	1.4	1.									
10	316.	55.9	20.3	9.9	5.7	3.6	2.4	1.7	1.								
11	401.	70.9	25.	12.5	7.2	4.6	3.1	2.2	1.3								
12	499.	88.2	32.	15.6	8.9	5.7	3.8	2.8	1.6	1.							
13	609.	108.	39.1	19.	10.9	7.1	4.7	3.4	1.9	1.2							
14	733.	130.	47.	22.9	13.1	8.3	5.7	4.1	2.3	1.5	1.						
15	787.	154.	55.9	27.2	15.6	9.9	6.7	4.8	2.8	1.7	1.2						
16		181.	65.7	32.	18.3	11.7	7.9	5.7	3.2	2.1	1.4	1.					
17		211.	76.4	37.2	21.3	13.5	9.2	6.6	3.8	2.4	1.6	1.2					
18		243.	88.2	43.	24.6	15.6	10.6	7.6	4.3	2.8	1.9	1.3	1.				
19		278.	101.	49.1	28.1	17.8	12.1	8.7	4.8	3.2	2.1	1.5	1.1				
20		316.	115.	55.9	32.	20.3	13.8	9.9	5.7	3.6	2.4	1.7	1.3	1.			
22		401.	146.	70.9	40.6	25.7	17.5	12.5	7.2	4.6	3.1	2.2	1.7	1.3			
24		499.	181.	88.2	50.5	32.	21.8	15.6	8.9	5.7	3.8	2.8	2.1	1.6	1.		
30								27.2	15.6	10.0	6.7	4.8	3.6	2.8	1.75	1.0	
36									24.6	15.6	10.6	7.6	5.7	4.3	2.76	1.6	1.0

Hydraulics of Single Pipe Lines

By D. R. TAYLOR

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THERE are few public water supplies that are not occasionally confronted with the problem of augmenting existing distribution mains or feeder mains to serve suburban areas of doubtful future growth, or surprisingly successful subdivisions which have outgrown the capacity of present facilities.

The problem is usually one of lessening the friction loss to provide more residual pressure or of increasing the rate of flow, or both.

The purpose of this article is to present and explain a simplified solution of such problems by use of simple arithmetic. The method described provides a quick method for those who are experienced with the use of the Hazen and Williams formula and also for those who are unfamiliar with the use of logarithms, the log log slide rule or the hydraulic slide rule.

Tables have been prepared and one formula has been reduced to a form involving only squares and square roots, all to eliminate the necessity of calculations with fractional exponentials.

To solve such problems, it is necessary to know the actual diameter of the pipes involved, because nominal diameters, in some cases, do not indicate relative capacities and friction losses closely enough. For instance, some three-inch cast iron pipe is actually three and three-tenths inches in diameter with a friction loss of only sixty-three percent of that indicated by its nominal diameter. Nominal and actual diameters are shown in Table 1. The diameters used for all galvanized pipe are for standard weight steel pipe and those for cast iron pipe are for 150 pounds pressure SuperdeLavaud bell and spigot and mechanical joint pipe conforming with Federal Specifications WW-P-421, except in sizes 1⅞" to 2¼" inclusive, which are sizes formerly or presently manufactured by several foundries and by various methods, for 150 pounds pressure or more.

The actual diameter of SuperdeLavaud mechanical joint pipe is the same as that for bell and spigot pipe in sizes from 3" to 12" inclusive. However, the diameter differs for sizes larger than 12". Actual diameter for both types are shown for sizes 14" to 20" inclusive. The bell letters "CI" and the mechanical joint pipe by the letters "CIM."

Relative capacities and friction losses of pipes, based on actual diameters, are shown in Table 2. The main portion of the table is for galvanized steel and bell and spigot cast iron pipe. Mechanical joint cast iron pipe (indicated as CIM) is included in the table as an insert.

The upper figure in each block in Table 2 is the comparative capacity or rate of flow expressed as a multiplier. The fractional figures beneath in the same block is the comparative friction loss expressed as per cent, as compared with the capacity and friction loss of any other size of pipe shown in the vertical columns at the extreme left and right.

For instance, the capacity of a 16" cast iron B & S pipe is 2.25 times or 225 per cent of that for a 12" cast iron B & S pipe when the friction loss is the same. The friction loss is only .224 times or 22.4 per cent of that for the 12" pipe for the same rate of flow. The corresponding values for 16" cast iron mechanical joint pipe as compared with 12" cast iron B & S pipe are 2.11 and .253 respectively (see insert Table 2).

Formulas:
When:
Q = gallons per minute
S = friction loss in pounds per square inch
D = diameter in inches
De = equivalent diameter in inches
Q_1 S_1 D_1 = values known or considered first
Q_2 S_2 D_2 = values unknown or considered second

$$Q_2 = Q_1 \left[\frac{S_2}{S_1}\right]^{0.54} \quad (1)$$

$$S_2 = S_1 \left[\frac{Q_2}{Q_1}\right]^{1.85} \quad (2)$$

$$S_2 = S_1 \left[\frac{D_1}{D_2}\right]^{4.87} \quad (3)$$

$$De = 0.92\sqrt{D_1^2 + D_2^2} \quad (4)$$

$$Q_2 = Q_1 \left[\frac{D_2}{D_1}\right]^{2.63} \quad (5)$$

If any type of pipe is involved, other than those shown in Table 2, the actual diameter should be determined and relative capacity and friction loss calculated by formulas (5) and (3) respectively.

The Design Process

Problem 1

Assume that a 4" cast iron main (of any length) serving one or more suburban sub-divisions has become inadequate and that it is decided to replace this main with a 6" cast iron main.

A. What increase in rate of flow may be expected with the same friction loss?

2.88 times or 288% (Table 2)

B. What friction loss may be expected with the same rate of flow?

.142 times or 14.2%

C. What rate of flow may be expected with only one-half of the former friction loss? Assume that the former friction loss was unity (1.0).

$$Q_2 = Q_1 \left[\frac{S_2}{S_1}\right]^{0.54} \quad \text{Formula (1)}$$

$$Q_2 = 2.88 \left[\frac{S_2}{S_1}\right]^{0.54}$$

$$= 2.88 \left[\frac{.5}{1}\right]^{0.54}$$

$$= 2.88\ (.5)^{0.54}$$

From Table 4, $(.5)^{0.54} = .687$

$Q_2 = 2.88 \times .687 = 1.98$ or an increase of 98%

D. What friction loss may be expected with only 50% more flow? Assume that the former flow was unity (1.0).

$$S_2 = .142 \left[\frac{1.50}{1}\right]^{1.85}$$

$$= .142\ (1.50)^{1.85}$$

From Table 3, $(1.50)^{1.85} = 2.12$

$S_2 = .142 \times 2.12 = .301$ or only 30.1% of the former friction loss

Problem 2

Assume the same conditions as in problem 1 and assume that it is desired to replace only enough of the 4" main with 6" main to reduce the friction loss 25%.

Table 1
NOMINAL AND ACTUAL DIAMETERS OF PIPES IN INCHES

Nominal	Actual	Nominal	Actual	Nominal	Actual	Nominal	Actual
½ Galv	.622	2 Galv	2.067	4 CI	4.12	16 CIM	16.20
¾ Galv	.824	2⅛ CI	2.125	6 CI	6.16	16 CI	16.60
1 Galv	1.049	2¼ CI	2.25	8 CI	8.21	18 CIM	18.20
1¼ Galv	1.380	2½ Galv	2.469	10 CI	10.16	18 CI	18.62
1½ Galv	1.610	3 Galv	3.068	12 CI	12.20	20 CIM	20.24
1⅞ CI	1.875	3 CI	3.30	14 CIM*	14.20	20 CI	20.70
2 CI	2.00	4 Galv	4.026	14 CI	14.55		

*CIM—Mechanical Joint Cast Iron Pipe.

TABLE 2
RELATIVE CAPACITY AND FRICTION LOSSES THROUGH PIPES
(Based on Actual Diameters)

	½ Galv	1 Galv	1¼ Galv	1½ Galv	1¾ CI	2 CI	2 Galv	2½ CI	2½ CI	2½ Galv	3 Galv	3 CI	4 Galv	4 CI	6 CI	8 CI	10 CI	12 CI	14 CI	16 CI	18 CI	20 CI	
½ Galv	2.09 .25	3.95 .078	8.1 .021	12.2 .01	18.0 .005																		½ Galv
¾ Galv		1.89 .31	3.88 .08	5.84 .01	8.7 .018	10.3 .013	11.2 .011	12.1 .01															¾ Galv
1 Galv			2.06 .26	3.08 .124	4.62 .038	5.5 .043	6.0 .036	6.4 .032	7.48 .024	9.5 .016	16.7 .005												1 Galv
1¼ Galv				1.49 .47	2.25 .224	2.66 .163	2.88 .14	3.18 .128	3.62 .092	4.6 .058	8.2 .021	9.9 .014											1¼ Galv
1½ Galv					1.49 .47	1.76 .348	1.93 .29	2.07 .258	2.42 .195	3.09 .125	5.45 .044	6.6 .03	11.2 .011										1½ Galv
1¾ CI						1.18 .73	1.29 .62	1.38 .55	1.65 .394	2.05 .264	3.64 .09	4.42 .054	7.5 .024	7.9 .022									1¾ CI
2 CI							1.09 .85	1.17 .74	1.36 .563	1.74 .358	3.08 .125	3.74 .098	6.3 .033	6.7 .03	19.2 .004								2 CI
2 Galv								1.08 .89	1.25 .657	1.59 .42	2.83 .145	3.42 .10	5.76 .038	6.1 .034	17.7 .005								2 Galv
2½ CI									1.16 .753	1.48 .48	2.61 .17	3.18 .12	5.38 .044	5.71 .042	16.4 .005	35.0 .001							2½ CI
2½ CI										1.28 .635	2.26 .22	2.76 .153	4.63 .058	4.93 .052	14.2 .008	30.5 .002							2½ CI
2½ Galv											1.77 .347	2.15 .24	3.62 .093	3.85 .082	11.2 .012	23.6 .003							2½ Galv
3 Galv												1.21 .70	2.08 .26	2.17 .237	6.3 .033	13.2 .008	23.2 .003						3 Galv
3 CI													1.69 .38	1.79 .34	5.15 .048	11.0 .011	19.2 .004	31.2 .002					3 CI
4 Galv														1.06 .867	3.06 .126	6.5 .031	11.4 .011	18.4 .005	29.2 .002	41.2 .001			4 Galv
4 CI															2.88 .142	6.1 .035	10.8 .012	17.4 .005	27.5 .002	39.0 .001	19.6 .001		4 CI
6 CI																2.12 .246	3.72 0.87	6.0 .036	9.6 .015	13.5 .008	18.2 .005		6 CI
8 CI																	1.75 .355	2.84 .145	4.5 .062	5.98 .036	8.63 .018	11.4 .011	8 CI
10 CI																		1.62 .41	2.57 .172	3.42 .103	4.94 .053	6.5 .031	10 CI
12 CI																			1.58 .43	2.25 .224	3.04 .127	4.0 .076	12 CI
14 CIM						1.41 .523	1.92 .298	2.54 .178												1.32 .598	1.91 .301	2.52 .18	14 CI
16 CIM							1.36 .567	1.8 .337													1.35 .570	1.91 .303	16 CI
18 CIM								1.35 5.73														1.32 .598	18 CI

Mechanical Joint

	14 CIM	16 CIM	18 CIM	20 CIM
4 Galv	27.5 .002	38.8 .001		
4 CI	25.9 .002	37.0 .001	49.6 .001	
6 CI	9.06 .012	12.7 .009	17.2 .005	23.0 .003
8 CI	4.23 .07	5.95 .047	8.1 .021	10.8 .012
10 CI	2.42 .196	3.42 .103	4.62 .058	6.14 .035
12 CI	1.49 .48	2.11 .253	2.86 .143	3.8 .085
14 CIM		1.41 .523	1.92 .298	2.54 .178
16 CIM			1.36 .567	1.8 .337
18 CIM				1.35 5.73

A. What per cent of the length of the 4″ main should be replaced with 6″ main?

Assume that the present friction loss of the 4″ main is unity or 1.0. From table 2, the friction loss of the 6″ is .142.

1.0 − .142 = .858, which is the difference in friction loss in per cent, for any length.

.25 ÷ .858 = .292

Therefore, to reduce the friction loss of the 4″ main 25%, it will be necessary to replace 29.2% of its length with 6″ main.

B. What per cent of the 4″ main should be replaced with 6″ main to increase the rate of flow 25% (from 1.0 to 1.25) with the friction loss remaining the same?

To increase the flow to 1.25 it will be necessary to decrease the total friction loss to a sum, that can be designated as x, which when divided into 1.0 (the present friction loss) will equal $(1.25)^{1.85}$

From table 3 $(1.25)^{1.85} = 1.51$—see formulas (1) and (2).

Then, $1 \div x = 1.51$, and

$x = 1.0 \div 1.51 = .661 =$ desired total friction loss.

1.0 − .661 = .339 = necessary reduction in friction loss (33.9%).

1.0 − .142 = .858 (see problem 2A).

.339 ÷ .858 = .395 = 39.5% of 4″ main to be replaced with 6″ to increase the flow 25% with the same friction loss.

The proof of this calculation, which is also applicable to any similar problem, when proof is desired, is as follows:

If the friction loss of the present 4″ main is 1.00 and 39.5% is replaced with 6″ main, the friction

Table 3
1.85th Power of Numbers
(1.10 to 5.0)

No.	1.10	1.20	1.25	1.30	1.40	1.50	1.60	1.70	1.75
Power	1.19	1.40	1.51	1.62	1.86	2.12	2.37	2.66	2.82

No.	1.80	1.90	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Power	2.97	3.28	3.6	5.45	7.62	10.15	13.0	16.2	19.6

Table 4
0.54th Power of Decimal Fractions
(.10 to 1.0)

No.	.10	.20	.25	.30	.40	.50	.60	.70	.75	.80	.90	1.0
Power	.288	.42	.473	.522	.61	.687	.758	.824	.856	.886	.945	1.0

loss of the remaining portion of the 4″ main will be .605 (1.0 — .395 = .605). The friction loss of the 39.5% of 6″ will be .0561 (.395 × .142 = .0561).

The total friction loss after the replacement will be,

for the 4″ — .6050
for the 6″ — .0561

Total — .6611
1.0 ÷ .6611 = 1.51

$Q_2=(1.51)^{0.54}=1.25$ or 125%. Formula 1

C. To reduce the friction loss 25% and also increase the flow of 25% requires the replacement of:

29.2% to reduce the friction loss and
39.5% to increase the flow

68.7% = total replacement.

Problem 3

Assume the same conditions as in problem 1, except that it is considered more expedient to parallel a portion of the 4″ main with 6″ main.

A. What per cent of the 4″ main should be paralleled with 6″ main to decrease the friction loss 25%? In this instance, it is necessary to determine the equivalent diameter of the 4″ and 6″ mains.

By formula 4, $De=0.92\sqrt{(4.12)^2+(6.16)^2}$
$=0.92\sqrt{54.91}$
$=6.817''$

Relative friction loss for 4″ and 6.817″ mains is by formula (3),

$$S_2=^1\left[\frac{4.12}{6.817}\right]$$
$$=1\times(.604)^{4.87}$$

From table 5, $(.60)^{4.87}=.084$
By interpolation (table 5), $(.604)^{4.87}=.0864$, say .086

Therefore, the friction loss of the equivalent main (6.817″) is 8.6% of that of the 4″ main.

To determine the per cent of 4″ main to be parallel with 6″ main to reduce the friction loss 25%, proceed as in problem 2A.

Table 5
4.87TH POWER OF DECIMAL FRACTIONS
(.20 to .99)

	.00	.0	.02	.03	.04	.05	.06	.07	.08	.09
.2	.0004	.0005	.0006	.0008	.001	.0012	.0015	.0017	.002	.0025
.3	.0028	.0034	.004	.0045	.0053	.006	.007	.008	.009	.0103
.4	.0115	.013	.0148	.0165	.0182	.0206	.023	.0256	.028	.031
.5	.0343	.038	.0417	.046	.05	.055	.06	.065	.071	.077
.6	.084	.09	.0975	.106	.115	.1225	.1325	.1425	.154	.165
.7	.176	.188	.20	.216	.231	.247	.2635	.281	.30	.3175
.8	.338	.36	.381	.405	.429	.455	.48	.508	.5375	.5675
.9	.600	.6315	.666	.7025	.74	.7785	.82	.862	.9063	.9523

1.0—.086=.914
.25÷.914=.274=27.4% to be paralleled.

B. To determine what per cent should be paralled to increase the flow 25%, proceed as in problem 2B.

X=1÷1.51=.661
1.0—.661=.339
.339÷.914=.371=37.1% to be paralleled.

C. To reduce the friction loss 25% and also increase the flow 25% requires the paralleling of:

27.4% to reduce the friction loss and
37.1% to increase the flow

64.5% = total per cent paralleled.

Problem 4

A customer seeks advice. He can operate two lawn sprinklers at the rear of his property, from the end of his long line of ¾″ pipe, but he desires 50% more flow so that he can operate three sprinklers.

From table 2, a 1″ pipe will furnish 1.89 times or 89% more water, but only 50% more is desired. How much of the ¾″ pipe should be replaced with 1″?

From table 3 $(1.50)^{1.86}=2.12$.

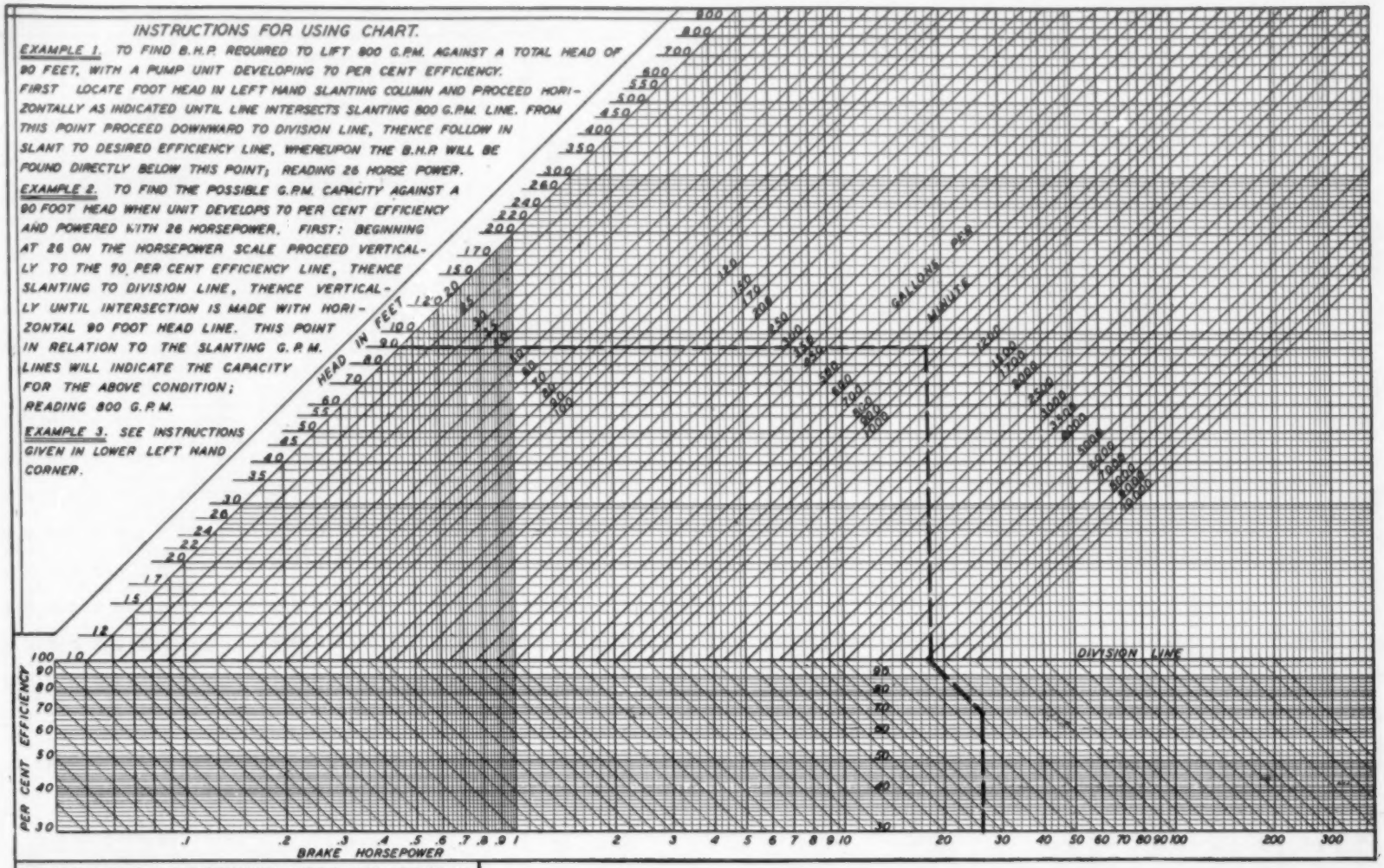
X=1.0÷2.12=.472
1.0—.472=.528

From table 2, the friction loss for 1″ is .31 or 31% of that for ¾″.

1.0—.31=.69
.528÷.69=.765=76.5% of the ¾″ to be replaced with 1″ to increase the flow 50%.

NUMBER OF TAPS THAT CAN BE TAKEN FROM PIPE OF VARIOUS SIZES

Diameter of Pipe in Inches	SIZE OF TAPS IN INCHES																							
	¾	1	1¼	1½	2	2½	3	3½	4	4½	5	6	7	8	9	10	12	14	15	16	18	20	22	24
2	11	5	3	2	1																			
2½	20	9	5	3	1	1																		
3	32	15	8	5	2	1	1																	
3½	47	22	13	8	4	2	1	1																
4	65	32	18	11	5	3	2	1	1															
4½	88	42	24	15	7	4	2	1	1	1														
5	114	55	32	20	9	5	3	2	1	1	1													
6	181	88	50	32	15	8	5	3	2	2	1	1												
7	266	129	74	47	22	13	8	5	4	3	2	1	1											
8	371	181	103	65	32	18	11	7	5	4	3	2	1	1										
9		243	139	88	42	24	15	10	7	5	4	2	1	1	1									
10		316	181	114	55	32	20	13	9	7	5	3	2	1	1	1								
12			285	181	88	50	32	21	15	11	8	5	3	2	2	1	1							
14			419	266	129	74	47	32	22	17	13	8	5	4	3	2	1	1						
15				316	154	88	55	38	27	20	15	9	6	4	3	2	1	1	1					
16				371	181	103	65	44	32	23	18	11	7	5	4	3	2	1	1	1				
18					243	139	88	59	42	32	24	15	10	7	5	4	2	1	1	1	1			
20					316	181	114	78	55	41	32	20	13	9	7	5	3	2	2	1	1	1		
22						229	145	99	70	52	40	25	17	12	9	7	4	3	2	2	1	1	1	
24						285	181	123	88	65	50	32	21	15	11	8	5	3	3	2	2	1	1	1


INSTRUCTIONS FOR USING CHART.
EXAMPLE 1. TO FIND B.H.P. REQUIRED TO LIFT 800 G.P.M. AGAINST A TOTAL HEAD OF 90 FEET, WITH A PUMP UNIT DEVELOPING 70 PER CENT EFFICIENCY. FIRST LOCATE FOOT HEAD IN LEFT HAND SLANTING COLUMN AND PROCEED HORIZONTALLY AS INDICATED UNTIL LINE INTERSECTS SLANTING 800 G.P.M. LINE. FROM THIS POINT PROCEED DOWNWARD TO DIVISION LINE, THENCE FOLLOW IN SLANT TO DESIRED EFFICIENCY LINE, WHEREUPON THE B.H.P. WILL BE FOUND DIRECTLY BELOW THIS POINT; READING 26 HORSE POWER.
EXAMPLE 2. TO FIND THE POSSIBLE G.P.M. CAPACITY AGAINST A 90 FOOT HEAD WHEN UNIT DEVELOPS 70 PER CENT EFFICIENCY AND POWERED WITH 26 HORSEPOWER. FIRST: BEGINNING AT 26 ON THE HORSEPOWER SCALE PROCEED VERTICALLY TO THE 70 PER CENT EFFICIENCY LINE, THENCE SLANTING TO DIVISION LINE, THENCE VERTICALLY UNTIL INTERSECTION IS MADE WITH HORIZONTAL 90 FOOT HEAD LINE. THIS POINT IN RELATION TO THE SLANTING G.P.M. LINES WILL INDICATE THE CAPACITY FOR THE ABOVE CONDITION; READING 800 G.P.M.
EXAMPLE 3. SEE INSTRUCTIONS GIVEN IN LOWER LEFT HAND CORNER.
HEAD IN FEET
GALLONS PER MINUTE
DIVISION LINE
PER CENT EFFICIENCY
BRAKE HORSEPOWER
EXAMPLE 3. TO FIND THE EFFICIENCY A PUMP MUST DEVELOP IN ORDER TO DELIVER 800 G.P.M. AGAINST A 90 FOOT HEAD WITH 26 HORSEPOWER. PROCEED AS IN EXAMPLE 1 TO DIVISION LINE, THEN SLANTWISE UNTIL INTERSECTION IS MADE WITH THE VERTICAL 26 HORSEPOWER LINE. THIS POINT WILL LOCATE THE HORIZONTAL EFFICIENCY LINE; READING 70 PER CENT.

Courtesy Peerless Pump Bull.

Relationship between Head, Capacity, Efficiency and Horsepower

Any three known factors determine the fourth

Contents of Cylindrical Tanks

By W. F. SCHAPHORST
Mech. Engr., Newark, N.J.

FIGURING the gallons in a vertical cylindrical tank takes time, and errors are often made in longhand figuring. The accompanying chart quickly gives the number of gallons in a vertical tank of this kind, of ordinary size, and even beyond the ordinary sizes.

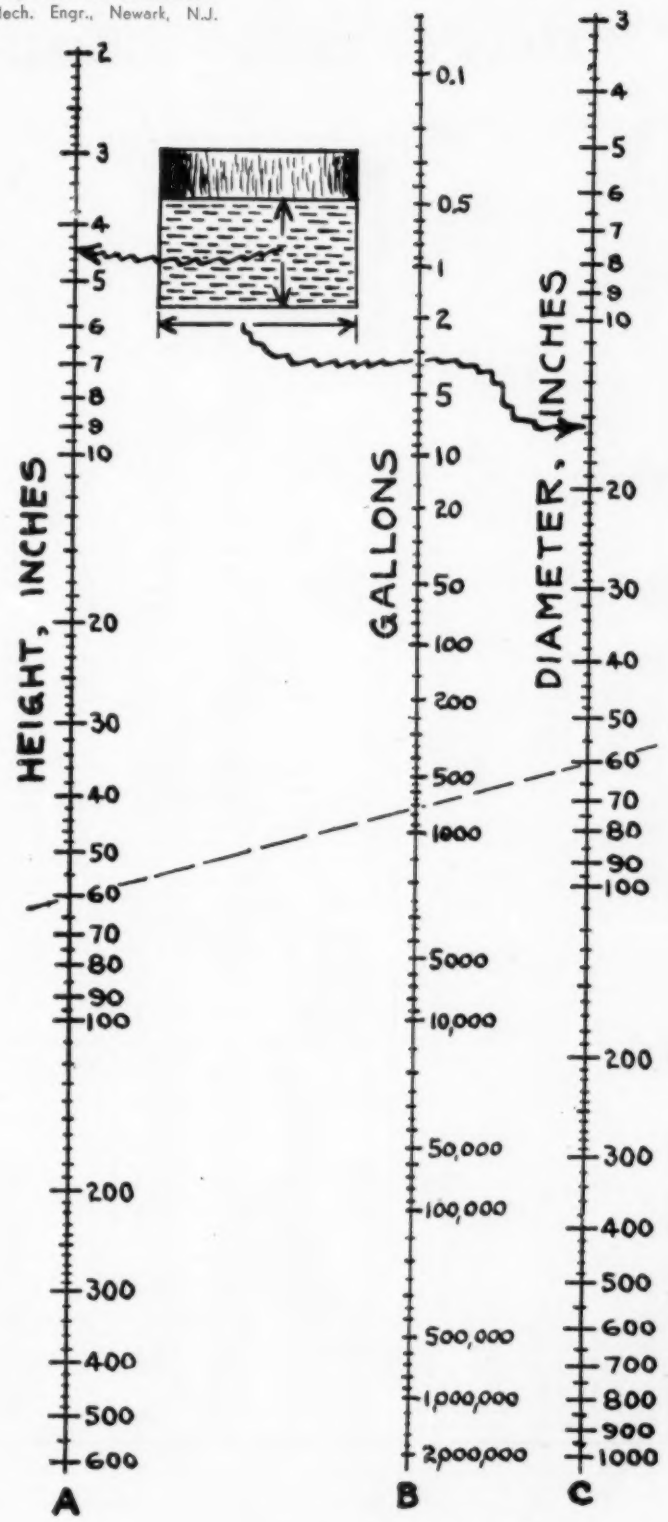
For example, how many gallons will be held by a cylindrical tank 60″ high by 60″ in diameter? The dotted line drawn across the chart shows how it is done. Connect the 60 in the height column (A) with the 60 in the diameter column (C) and the answer is shown in the volume column (B) to be very close to 740 gallons. Figure it out in longhand or on a slide rule and you will find that the answer is 733 gallons, showing that the chart is sufficiently accurate for general use over a wide range of tank sizes.

Inversely the chart may be used to figure the size of tank that will hold a certain number of predetermined gallons. Thus if a tank is wanted to hold 740 gallons, simply run any straight line through the 740 in column (B) and the intersection with column (A) gives the height, and the intersection of the same line with column (C) gives the diameter. By swinging a straight line around the desired point in column (B) the most economical height and diameter combination is readily obtained. As will be observed, there are hundreds and thousands of combinations possible to hold 740 gallons. Also, if we should have a tank 60″ in diameter and, say, 200″ high, and it should be desired to pour only 740 gallons into it, the same dotted line drawn across this chart will show that by filling the tank to a height of 60″ it will contain 740 gallons.

The range of the chart, as will be observed, is very great. It will take care of any tank all the way from 2″ in height to 600″ in height, and any diameter from 3″ to 1000″. The maximum capacity of the largest tank is given as 2,000,000 gallons. The chart is based on the U.S. standard of 231 cubic inches per gallon.

Just as an "exercise," what, for instance, must be the dimensions of a tank (can) to hold exactly one gallon? Any line through the "one" in column (B) will give combinations of two dimensions—in fact hundreds of them. One of the combinations will be found to be 6″ high by 7″ in diameter. It will also be found that a flat-shaped tank (can) 3″ high by 10″ in diameter comes very close to having a capacity of one gallon. Or, if 20″ high by 4″ in diameter this combination will hold one gallon. The number of possible combinations is endless.

If the chart is used a few times you will keep it in a convenient place in your work desk.



AREAS OF CIRCLES—SQUARES—SQUARE ROOTS

(Also Fractions to Decimal Equivalent.)

No. N Fraction	Decimal	N^2	$\sqrt{N}$	Area Circle (N = Diam.)	No. N	N^2	$\sqrt{N}$	Area Circle (N = Diam.)	No. N	N^2	$\sqrt{N}$	Area Circle (N = Diam.)	No. N	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
1/16	.0625	.0039	.2500	.0031	10	100	3.162	78.54	76	5776	8.718	4536.5	142	20164	11.92	15837
1/8	.125	.0156	.3536	.0125	11	121	3.317	95.03	77	5929	8.775	4656.6	143	20449	11.96	16061
3/16	.1875	.0352	.4330	.0276	12	144	3.464	113.1	78	6084	8.832	4778.4	144	20736	12.00	16286
1/4	.25	.0625	.5000	.0491	13	169	3.606	132.7	79	6241	8.888	4901.7	145	21025	12.04	16583
5/16	.3125	.0977	.5590	.0767	14	196	3.742	153.9	80	6400	8.944	5026.5	146	21316	12.08	16742
3/8	.375	.1406	.6124	.1105	15	225	3.873	176.7	81	6561	9.000	5153.0	147	21609	12.12	16972
7/16	.4375	.1914	.6614	.1503	16	256	4.000	201.1	82	6724	9.055	5281.0	148	21904	12.17	17203
1/2	.50	.2500	.7071	.1964	17	289	4.123	227.0	83	6889	9.110	5410.6	149	22201	12.22	17437
9/16	.5625	.3164	.7500	.2485	18	324	4.243	254.5	84	7056	9.165	5541.8	150	22500	12.25	17671
5/8	.625	.3906	.7906	.3068	19	361	4.359	283.5	85	7225	9.220	5674.5	151	22801	12.29	17908
11/16	.6875	.4727	.8297	.3712	20	400	4.472	314.2	86	7396	9.274	5808.8	152	23104	12.33	18146
3/4	.75	.5625	.8660	.4418	21	441	4.583	346.4	87	7569	9.327	5944.7	153	23409	12.37	18385
13/16	.8125	.6602	.9014	.5185	22	484	4.690	380.1	88	7744	9.381	6082.1	154	23716	12.41	18627
7/8	.875	.7656	.9354	.6013	23	529	4.796	415.5	89	7921	9.434	6221.1	155	24025	12.45	18869
15/16	.9375	.8789	.9683	.6903	24	576	4.899	452.4	90	8100	9.487	6361.7	156	24336	12.49	19113
1	1.	1.000	1.000	.7854	25	625	5.000	490.9	91	8281	9.539	6503.9	157	24649	12.53	19359
1 1/16	1.125	1.266	1.061	.9940	26	676	5.099	530.9	92	8464	9.592	6647.6	158	24964	12.57	19607
1 1/4	1.25	1.563	1.118	1.227	27	729	5.196	572.6	93	8649	9.644	6792.9	159	25281	12.61	19856
1 3/8	1.375	1.891	1.175	1.485	28	784	5.292	615.8	94	8836	9.695	6939.8	160	25600	12.65	20106
1 1/2	1.50	2.250	1.225	1.767	29	841	5.385	660.5	95	9025	9.747	7088.2	161	25921	12.69	20358
1 5/8	1.625	2.641	1.275	2.074	30	900	5.477	706.9	96	9216	9.798	7238.2	162	26244	12.73	20613
1 3/4	1.75	3.063	1.323	2.405	31	961	5.568	754.8	97	9409	9.849	7389.8	163	26569	12.77	20867
1 7/8	1.875	3.516	1.369	2.761	32	1024	5.657	804.2	98	9604	9.900	7543.0	164	26896	12.81	21124
2	2.	4.000	1.414	3.142	33	1089	5.745	855.3	99	9801	9.950	7697.7	165	27225	12.85	21382
2 1/8	2.125	4.516	1.458	3.547	34	1156	5.831	907.9	100	10000	10.00	7854.0	166	27556	12.88	21642
2 1/4	2.25	5.063	1.500	3.976	35	1225	5.916	962.1	101	10201	10.05	8011.9	167	27889	12.92	21904
2 3/8	2.375	5.641	1.541	4.430	36	1296	6.000	1017.9	102	10404	10.10	8171.3	168	28224	12.96	22168
2 1/2	2.50	6.250	1.581	4.909	37	1369	6.083	1075.2	103	10609	10.15	8332.3	169	28561	13.00	22432
2 5/8	2.625	6.891	1.620	5.412	38	1444	6.164	1134.1	104	10816	10.20	8494.9	170	28900	13.04	22698
2 3/4	2.75	7.563	1.658	5.940	39	1521	6.245	1194.6	105	11025	10.25	8659.0	171	29241	13.08	22966
2 7/8	2.875	8.266	1.696	6.492	40	1600	6.325	1256.7	106	11236	10.30	8824.7	172	29584	13.11	23235
3	3.	9.000	1.732	7.069	41	1681	6.403	1320.3	107	11449	10.34	8992.0	173	29929	13.15	23506
3 1/8	3.125	9.766	1.768	7.670	42	1764	6.481	1385.4	108	11664	10.39	9160.9	174	30276	13.19	23779
3 1/4	3.25	10.56	1.803	8.296	43	1849	6.557	1452.2	109	11881	10.44	9331.3	175	30625	13.23	24053
3 3/8	3.375	11.39	1.837	8.946	44	1936	6.633	1520.5	110	12100	10.49	9503.3	176	30976	13.27	24328
3 1/2	3.50	12.25	1.871	9.621	45	2025	6.708	1590.4	111	12321	10.54	9676.9	177	31329	13.30	24606
3 5/8	3.625	13.14	1.904	10.32	46	2116	6.782	1661.9	112	12544	10.58	9852.0	178	31684	13.34	24885
3 3/4	3.75	14.06	1.937	11.04	47	2209	6.856	1734.9	113	12769	10.63	10029	179	32041	13.38	25165
3 7/8	3.875	15.02	1.969	11.79	48	2304	6.928	1809.6	114	12996	10.68	10207	180	32400	13.42	25447
4	4.	16.00	2.000	12.57	49	2401	7.000	1885.7	115	13225	10.72	10387	181	32761	13.45	25730
4 1/8	4.125	17.02	2.031	13.36	50	2500	7.071	1936.5	116	13456	10.77	10568	182	33124	13.49	26016
4 1/4	4.25	18.06	2.062	14.19	51	2601	7.141	2042.8	117	13689	10.82	10751	183	33489	13.53	26302
4 3/8	4.375	19.14	2.092	15.03	52	2704	7.211	2123.7	118	13924	10.86	10936	184	33856	13.56	26590
4 1/2	4.50	20.25	2.121	15.90	53	2809	7.280	2206.2	119	14161	10.91	11122	185	34225	13.60	26880
4 5/8	4.625	21.39	2.151	16.80	54	2916	7.349	2290.2	120	14400	10.95	11310	186	34596	13.64	27172
4 3/4	4.73	22.56	2.180	17.72	55	3025	7.416	2375.8	121	14641	11.00	11499	187	34969	13.67	27465
4 7/8	4.875	23.77	2.208	18.67	56	3136	7.483	2463.0	122	14884	11.05	11690	188	35344	13.71	27759
5	5.00	25.00	2.236	19.64	57	3249	7.500	2551.8	123	15129	11.09	11882	189	35721	13.75	28055
5 1/4	5.25	27.56	2.291	21.65	58	3364	7.616	2642.1	124	15376	11.14	12076	190	36100	13.78	28353
5 1/2	5.50	30.25	2.345	23.76	59	3481	7.681	2734.0	125	15625	11.18	12272	191	36481	13.82	28652
5 3/4	5.75	33.06	2.398	25.97	60	3600	7.746	2827.4	126	15876	11.23	12469	192	36864	13.86	28953
6	6.	36.00	2.450	28.27	61	3721	7.810	2922.5	127	16129	11.27	12668	193	37249	13.89	29255
6 1/4	6.25	39.06	2.500	30.68	62	3844	7.874	3019.1	128	16384	11.31	12868	194	37636	13.93	29559
6 1/2	6.50	42.25	2.550	33.18	63	3969	7.937	3117.2	129	16641	11.36	13070	195	38025	13.96	29865
6 3/4	6.75	45.56	2.598	35.78	64	4096	8.000	3217.0	130	16900	11.40	13273	196	38416	14.00	30172
7	7.	49.00	2.646	38.48	65	4225	8.062	3318.3	131	17161	11.45	13478	197	38809	14.04	30481
7 1/4	7.25	52.56	2.693	41.28	66	4356	8.124	3421.2	132	17424	11.49	13685	198	39204	14.07	30791
7 1/2	7.50	56.25	2.739	44.18	67	4489	8.185	3525.7	133	17689	11.53	13893	199	39601	14.11	31103
7 3/4	7.75	60.06	2.784	47.17	68	4624	8.246	3631.7	134	17956	11.58	14103	200	40000	14.14	31416
8	8.00	64.00	2.828	50.27	69	4761	8.307	3739.3	135	18225	11.62	14314	...	.....	.....	.....
8 1/4	8.25	68.06	2.872	53.46	70	4900	8.367	3848.5	136	18496	11.66	14527	...	.....	.....	.....
8 1/2	8.50	72.25	2.916	56.75	71	5041	8.426	3959.2	137	18769	11.70	14741	...	.....	.....	.....
8 3/4	8.75	76.56	2.958	60.13	72	5184	8.485	4071.5	138	19044	11.75	14957	...	.....	.....	.....
9	9.00	81.00	3.000	63.62	73	5329	8.544	4185.4	139	19321	11.79	15175	...	.....	.....	.....
9 1/4	9.25	85.56	3.041	67.20	74	5476	8.602	4300.8	140	19600	11.83	15394	...	.....	.....	.....
9 1/2	9.50	90.25	3.082	70.88	75	5625	8.660	4417.9	141	19881	11.87	15615				
9 3/4	9.75	95.06	3.123	74.66												

X. BULLETINS AND CATALOGS

For Copies of any of the Bulletins or Catalogs Listed Below, Circle the Corresponding Numbers on the Inquiry Reply Card in this Section.

Activated Silca—See Silca

1R
Activated Sludge—Bulletin KRO-1 covers the Kraus Interchange Process for the treatment and use of digester liquor in the activated sludge process.—Pacific Flush Tank Co.

2R
Aeration Equipment—Bulletin 265A covers both mechanical and jet aeration systems for activated sludge plants.—The American Well Works.

3R
Aeration Equipment—This booklet presents complete information on the development, design and application of both Walker Diffusair and Impingement aeration equipment. It includes discussions on channel aeration, grit aeration and details on the Walker Air Lift for return activated sludge pumping.—Walker Process Equipment Inc.

4R
Air Compressors—Bulletin SPB-56 illustrates and discusses 9 different portable air compressor models with capacities of from 20 to 600 cfm. Also listed are features such as: controlled temperature of compressed air; push-button starting; mechanically operated intake valves; and parts 90 percent interchangeable.— Schramm, Inc.

Air Valves—See valves

Altitude Valves—See valves

5R
Anthrafilt—Bulletin on the anthracite coal filter medium.—Anthracite Equipment Corp.

6R
Asbestos-Cement Pipe—A brief history of the use of asbestos and the advantages of "Century" asbestos-cement pipe. A chart of standard sizes and classes is included.—Keasbey & Mattison Co.

7R
Bar Screens—Bulletins 315-21 and 54-8A illustrate and discuss the Rex front cleaned and Rex heavy-duty bar screens. —Chain Belt Co.

8R
Bascule Gate—A 12 page bulletin with dimensions, description and typical installations of this crest gate for pond level and flood control.—S. Morgan Smith Co.

9R
Biofilters—Bulletin 7313 on small scale biofiltration with Dorr-Oliver Duo treatment units providing complete sewage treatment for institutions, housing developments and turnpike service areas.—Dorr-Oliver Inc.

10R
Blowers—Bulletin containing complete data for Type AF blowers 2 inch through 7 inch gear diameter. Also includes selection and dimension tables, performance characteristics and illustrations.—Roots-Connersville Blower Div.

11R
Blowers—"Centrifugal Blowers" is a bulletin on Multistage Type V Blowers for equivalent air pressure above 6.5 psig and inlet volumes above 1500 cfm.—Allis Chalmers Co.

Butterfly Valves—See valves

12R
Cable—G91-9 is a product specification on Bailey Armortube Cable for protection of pneumatic telemetering and automatic control system transmission lines from mechanical injury and corrosive atmospheres during and after installation.—Bailey Meter Co.

13R
Carbonation—A handbook containing information to aid engineers, plant operators and others concerned with carbonation of lime softened waters. Includes discussion of the background, chemical reactions, methods and problems in carbonation. Corrosion, due to impurities in CO_2 produced by certain methods, is thoroughly covered with tables giving corrosion resistance of various metals.—Walker Process Equipment Inc.

14R
Cast Iron Pipe—Complete line of Cast Iron Pressure Pipe in sizes of 3 to 24 inches diameter is listed in catalog 54. Complete specifications and construction details.—Alabama Pipe Co.

15R
Cathodic Protection—A series of three bulletins on cathodic protection: "Fighting Corrosion with Corrosion", "Cath-O-Chem System", and "Cathodic Protection for Water Works Plants."—Electro Rust-Proofing Corp.

Centrifugal Pumps—See Pumps

Check Valves—See valves

16R
Chemical Feeders—Bulletin 30-H12A on gravimetric loss-in-weight feeders; Bulletin 35-H5 on belt gravimetric feeders; Bulletins 20-J104 and 50-57A on volumetric feeders; all for adding chemicals for water or waste-treatment.—Omega Machine Co.

17R
Chemical Feeders—Publ. No. TP. 39M-4 describes dry chemical feeders of volumetric type.—Wallace & Tiernan, Inc.

18R
Chemicals—"Facts About Frontier" gives a complete description of the various chemicals, services and facilities of the company.—Frontier Chemical Co.

19R
Chemical Treatment—Bulletin A-705 discusses the use of chemicals in water and sewage treatment.—Columbia-Southern Chemical Corp.

20R
Chlorine—A bulletin describing the physical properties, handling methods, uses and containers.—Penn Salt Mfg. Co.

21R
Chlorine—Bulletin containing general information on the properties, containers, and handling of liquid chlorine.—Penn Salt Mfg. Co. of Washington.

22R
Chlorine—General information, prices, list of local distributors, shipping containers on liquid chlorine, calcium hypochlorite, and sodium hypochlorite.—John Wiley Jones Co.

23R
Chlorine Dioxide—A booklet discussing in detail the removal of tastes and odors by chlorine dioxide treatment and its bactericidal properties, methods of treatment and application. Economic factors and general installation instructions are also included.—Industrial chemicals Div., Olin-Mathieson Chemical Corp.

24R
Chlorine Feeders—A series of bulletins covering "Sterelators" both portable, wall, and large capacity models.—Everson Mfg. Corp.

25R
Chlorine Feeders—A series of bulletins on Chlorinizers, for feeding chlorine gas and other gases like ammonia, sulfur dioxide, etc. Capacities from 4 to 8000 lbs. per 24 hours.—Builders-Providence, Inc.

26R
Chlorine Feeders— Bulletins on chlorinators particularly for swimming pools. —Chemical Equipment Co.

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27R
Chlorine Feeders—Bulletin on V-Notch variable orifice chlorinator.—Wallace & Tiernan, Inc.

28R
Chlorine Feeders—Cat. File Nos. 20.100, 50, 110, present mechanical diaphragm vacuum type solution feeder and chlorine flow recorder.—Wallace & Tiernan, Inc.

29R
Chlorine Handling—Bulletin A-505 discusses the problem of the Safe Handling of Chlorine.—Columbia-Southern Chemical Corp.

30R
Chlorine Residual Recorder—Catalog 50.250 describes the WT Residual Chlorine Recorder as an instrument for measuring residual chlorine amperometrically in a continuous sample and recording the reading in parts per million on a 24 hour circular chart. Advantages, case histories, design features, operation and technical data are included.—Wallace & Tiernan, Inc.

31R
Chlorine Wall Chart—Chart describes container valves, leak detection, first aid and accident procedures.—Penn Salt Mfg. Co.

32R
Clamps and Saddles for Pipe Repair—Catalog GW gives complete description and specifications on all Skinner seal clamps and saddles. Also serves as a pipe repair manual.—M. B. Skinner Co.

33R
Clarifier—Bulletin 52-77 describes the Rex Verti-flo Clarifier for water and waste-water treatment.—Chain Belt Co.

34R
Clarifiers, Industrial Waste—Applications, flow diagrams and complete descriptions are given in bulletins 850 and 6051 on the Cyclator and Sediflotor clarifiers.—Infilco Inc.

35R
Cleaing Sewers—This brochure describes mobile units with specially designed rodding drive and controls, plus data on a reboring service that cleans clogged sewers and drains.—National Power Rodding Corp.

36R
Cleaning Water Mains—Literature describes mobile units with specially designed power rodding drive and central mechanism for reboring water mains to restore close to original capacity.—National Power Rodding Corp.

37R
Coal and Ash Handling—Two folders and a catalog on coal and ash handling layouts; also a catalog on chains, and a series of questions and answers on ash handling.—Beaumont-Birch Co.

38R
Comminutor—A 28-page engineering manual that describes and illustrates the 15 and 25 inch Worthington comminutors. Curves, drawings and information for selection, maintenance and installation of the comminutors are included.—Worthington Corp.

39R
Concrete Hardening—A bulletin explaining how sodium silicate hardens, dustproofs, acidproofs and oil proofs concrete.—Philadelphia Quartz Co.

40R
Concrete Pressure Sewer Pipe—A folder discussing features and standards of concrete pressure sewer pipe.—Price Brothers Co.

41R
Concrete Pressure Water Pipe—A booklet explaining and illustrating the proper method of laying concrete pressure pipe. The steps discussed are: digging the trench; checking grade; handling the pipe; lubricating joint rings; making the joint; checking the gasket; grade and line changes; completing the joint; bedding the pipe; and the use of pull jacks.—Price Brothers Co.

42R
Concrete Tanks—Bulletin on technical information on the design, construction and uses of prestressed concrete tanks.—Preload Co. Inc.

43R
Construction Tools—Illustrated 16 page catalog on rack drills; wagon drills; pavement breakers; clay spades; trench diggers; backfill tampers; drill steels; rock bits; air hose; and couplings.—Schramm, Inc.

44R
Control Drives—Product specification P31-1 describes piston-operated power positioning drives for butterfly valves and other final control elements.—Bailey Meter Co.

45R
Controllers—Catalog includes detailed specifications and control action descriptions and ratings for both electric and pneumatic controllers.—Minneapolis-Honeywell Regulator Co.

46R
Control System Instruments—Bulletin 7202 describes miniature instruments for pneumatic transmission and control for water filtration plants.—Minneapolis-Honeywell Regulator Co.

47R
Copper Sulphate—A 13-page booklet describing the use and application of sulphate in water treatment and algae control, and containing charts of chemicals required for various treatments.—Tennessee Corp.

48R
Copper Sulphate—Two booklets on the use of copper sulphate. "Copper sulphate in control of Microscopic Organisms", and "Copper sulphate for Root and Fungus Control in Sanitary Sewers and Storm Drains."—Phelps Dodge Refining Corp.

49R
Corrosion Control—A booklet on the description and the uses of Pitt Chem Tarset, a new coal tar-Epoxy resin coating for control of severe corrosive conditions—Pittsburgh Coke & Chemical Co.

50R
Couplings, Asbestos-Cement Pipe—Features and installation on instructions for the use of Century "Fluid-Tite" couplings are graphically presented along with a chart of standard sizes.—Keasbey & Mattison Co.

51R
Deodorants—A paper and two folders discuss the effective reduction of sewage and waste odors and the science of Osmics.—Airkem, Inc.

52R
Deodorants—Technical literature on Cifon N. Y. and Arodon used as deodorants in sewage disposal plants.—Fine Organics Inc.

53R
Demineralizers—Bulletin WC-111 discusses the design, theory, and equipment of ion exchange systems in detail. A cost estimating curve, system selection chart and other features are also included.—Graver Water Conditioning Co.

Diaphragm Slurry Pump—See Pump

54R
Diatomite Filters—Bulletin 1800-3 on diatomaceous earth filters.—Proportioneers, Inc.

Electric Motors—See Motors

55R
Elevated Steel Tanks—A 24-page booklet discusses Horton Elevated Steel Tanks of Large Capacity and describes the advantages of using large elevated steel tanks to provide gravity pressure. Also contained, detailed information on the design and construction of the tanks and 12 photographs of actual installations, a table of sizes, and page of drawings showing construction details.—Chicago Bridge & Iron Co.

56R
Elevated Steel Reservoirs and Standpipes—A 24-page booklet on Horton Steel Reservoirs and Standpipes. Illustrations show installations from 50,000 to 10,000,000 gal. capacity with cone, umbrella, or ellipsoidal roofs and ornamental structures with special architectural features. Also included are: table of standard capacities, information

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on foundations, advantage of pickling and painting, and data on the use of suction tank for fire protection.—Chicago Bridge & Iron Co.

57R

Elevated Storage—A brochure on standpipes and steel reservoirs discusses roof types, shows photos of erected tanks, and gives a list of standard reservoir dimensions—Pittsburgh-Des Moines Steel Co

58R

Elevated Storage—Bulletin describes and illustrates various types of steel structures for the storage of water.—Hammond Iron Works.

59R

Elevated Storage—General information on elevated steel tanks including the standard hemispherical self-supporting bottom and the Cole Ovaloid.—R. D. Cole Mfg. Co.

60R

Elevated Storage Tanks—A brochure, "Modern Water Storage in Elevated Tanks" gives a description of elevated tank types, standard sizes, photos of erected tanks and a listing of accessory equipment.—Pittsburgh-Des Moines Steel Co.

61R

Elevated Storage Tanks—Tables and photographs of standard Nooter water storage reservoirs, standpipes and elevated tanks.—Nooter Corp.

62R

Fencing—A manual on planned plant protection by the use of steel chain link fencing.—Continental Steel Corp.

63R

Ferric Chloride, Anhydrous—A general information bulletin on the use of anhydrous ferric chloride in sewage and water treatment.—Penn Salt Mfg. Co. of Washington.

64R

Ferric-Floc—A 38-page booklet describing the use and application of ferric sulphate in all phases of coagulation—Tennessee Corp.

65R

Filter, Automatic Backwash Sand—Bulletin 46-A illustrates and describes Hardinge's automatic backwash sand filter.—Hardinge Co.

66R

Filter Bottoms—Descriptive material on perforated Transite plate filter underdrains.—Filtration Equip. Corp.

67R

Filter Membrane—Illustrated booklet reviews approximately 80 technical articles reporting application of this new analytical screening device in the study of gaseous and liquid suspended particles in the sub-micron range size.—Millipore Filter Corp.

68R

Filter Operating Panels—A product specification sheet and drawing discussing steel control panels for rapid sand filter operation. Each panel features inclined surface for optimum readability of the instruments and efficient operation of hand-automatic selector stations.—Bailey Meter Co.

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Filter Operating Tables—Describes two-tone, modern design, custom built to specifications filter tables made of Transite, ebony and Colorlith.—Filtration Equip. Corp.

70R

Filters—General information on Roberts filters for municipal water purification, industrial water rectification, swimming pool recirculating systems and pressure filters.—Roberts Filter Mfg. Co.

71R

Filter Underdrains—Brochure gives complete information on "Criscrete" filter underdrains.—M C G Company.

72R

Filter Underdrains, Sewage—Bulletin UF-3 provides complete information on the Natco Unifilter Block Underdrains for trickling filter beds of sewage disposal plants.—Natco Corp.

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Fire Hydrants—Bulletin G describes and illustrates complete line of fire hydrants.—Rensselaer Valve Co., Div.

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Floating Covers—Bulletin 332 presents descriptions, technical information and data and details of construction of floating covers for controlled digestion.—Pacific Flush Tank Co.

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Flocculation—Bulletins 2W66 and 2W72 cover impeller type and reel type flocculation units and rapid mixers for water and waste treatment.—Walker Process Equipment, Inc.

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Flocculation Equipment—An 8-page booklet, "Equipment For Chemical Flocculation" illustrates and discusses Link-Belts line of conveyors and elevators for handling chemicals and flash and straightline mixers.—Link-Belt Co.

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Flocculators—Bulletin 6971 contains a description of Dorr-Oliver equipment used to perform the two basic steps of flash mixing and flocculation.—Dorr-Oliver Inc.

78R

Floor Grating—A bulletin discussing riveted, pressure locked, and all welded types of floor grating. General instruction for ordering and charts on safe loads are given. Borden safety steps are also discussed.—Borden Metal Products Co.

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Flow Measurement and Instruments—General Catalog No. 005 covers equipment on meters and gauges.—Simplex Valve & Meter Co.

82R

Flow Tubes—The Gentile Flow Tube, used for metering water, air, slurry, raw sewage sludge, paper stock, etc. Advantages of the flow tube are given, along with a performance table, head loss and differential charts. Photographs of actual installations and cut-away drawings are included.—Foster Engineering Co.

Gages—See Instruments

83R

Gas Analyzer—A folder describing a supersensitive analyzer that is capable of measuring toxic and combustible gases in parts per billion.—Taller & Cooper Inc.

84R

Gas Safety Equipment—Bulletin 321 presents data, details and information on safety equipment for handling gas from sludge digesters.—Pacific Flush Tank Co.

Gate Valves—See Valves

85R

Grit Collection—Bulletin 315-41 covers Rex grit collectors for sewage and industrial waste plants.—Chain Belt Co.

86R

Heat Exchanger—Bulletin 23[illegible] describes and discusses the digester heater and heat exchanger for controlled sludge digestion.—Pacific Flush Tank Co.

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Heat Exchanger—Bulletin 6281 on the spiral heat exchanger, an external element of the spiral flow type for controlling digestion tank temperatures—Dorr-Oliver Inc.

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Hydrants and Valves—A general bulletin covering a complete line of hydrants and valves.—Darling Valve & Mfg. Co.

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Hydrants and Valves—Eighty page catalog covering cast iron pipe and fittings, fire hydrants and gate valves. Also listed are separate folders and bulletins covering individual products.—R D. Wood Co.

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Hydrofluosilicic Acid—A brochure on Hydrofluosilicic acid and it's uses for fluoridation by municipalities.—International Minerals & Chemical Corp.

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Hypochlorination—A 50 page booklet on "Hypochlorination of Water" gives a complete discussion on the proper treatment of water supplies and advantages of chlorinating, various chlorination practices and uses of HTH dosage tablets. Eight tables pertaining to chlorination are included.—Industrial Chemicals Div., Olin-Mathieson Chemical Corp.

92R

Hypochlorinator—A bulletin describing a heavy duty midget Chlor-O-Feeder as an all purpose, positive displacement, diaphragm pump for fluids such as hypochlorite, pH correctives, and abrasive slurries. The midget delivers 0.5 to 9 gph against pressures up to 85 pisg.—Proportioneers Inc.

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Hypochlorite—A bulletin giving general information on the use of Perchloron for swimming sanitation, water purification, and sewage disposal.—Penn Salt Mfg. Co. of Washington.

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Incinerators—Bulletin 104 presents incinerators for institutional and industrial wastes.—Morse-Boulger Destructor Co.

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Instruments and Gages—Includes detailed specifications of flow rate indicators, recorders and controllers.—Minneapolis-Honeywell Regulator Co.

103R

Ion Exchange Water Softener—Bulletin 2386A describes principles of operation and discusses manual and automatic valve operation.—Permutit Cc.

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Laboratory Equipment—General information regarding the company's line of laboratory equipment.—Phipps & Bird, Inc.

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Level Controls—Data sheets give details on Roto-Trols for: elevated tanks, standpipes and reservoirs; closed systems and booster systems; hydropneumatic or pressure tanks; sewage pumps; sequence control; and pressure operated sump control.—Healy-Ruff Co.

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Liquid Feeders, Rotodip—Bulletin 65-H12A on a volumetric feeder for liquids, including acids, alkalies, or slurries at rates from 0 to 1800 gallons per hour with repeatable accuracy within ±1%. Omega Machine Co.

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Liquid Level Control Measurement—A bulletin describing widely used instrumentation systems for measuring and controlling liquid level.—Minneapolis-Honeywell Regulator Co.

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Mechanical Jointed Clay Pipe—A 4-page folder describes the new AMVIT jointed vitrified clay pipe, sizes 4 through 24 inches as a true "built-in" mechanical joint ready for immediate, quick and easy installation. The joint is furnished on all standard fittings, as well as pipe, permitting a bottle tight line.—American Vitrified Products Co.

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Meters and Regulators, Gas—A catalog containing information, pictures and specifications for Rockwell sewage gas meters and gas pressure regulators.—Rockwell Mfg. Co.

111R

Meter Setting and Testing—Catalog 56 contains complete listing of water meter setting and testing equipment along with information on good meter setting practice under various conditions.—Ford Meter Box Co. Inc.

112R

Meters, Gas—A folder illustrating and discussing the features of Superior Tinned Steelcase Gas Meters with a complete list of meter specifications Superior Meter Co., Inc., Neptune Meter Co.

113R

Meters, Feeders and Controls—Bulletin B-1-F6 gives the complete line of flow meters, chemical feeders and control equipment used in water treatment and sewage disposal.—Builders-Providence Inc.

114R

Meters, Water—A catalog listing the complete line of water meters for customer's services.—Neptune Meter Co.

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Meters, Water—Catalog gives full details of American disc type water meters, both frost bottom and solid casing types, sizes ⅝ to 6 inches.—Buffalo Meter Co.

116R

Meter Testing, Water—A 40-page book on methods and equipment for testing meters, including information on meter shop layout, meter performance, and a bibliography on meter maintenance.—Ford Meter Box Co., Inc.

117R

Micro-Strainers—Brochure and leaflet on the application and installation of micro-strainers in water and sewage plants.—Glenfield & Kennedy, Inc.

118R

Motors, Electric—"A Guide to Care of Electric Motors".—Allis-Chalmers Mfg. Co.

119R

Motors, Electric.—"Handy Guide For Quick Selection of Electric Motors" is the title of a 12-page, 2-color reference brochure which provides a quick reference to data on Allis-Chalmers general purpose motors and covers information such as: Motor characteristics, squirrel cage motors, electrical modifications, dimensions, and motor controls.—Allis-Chalmers Mfg. Co.

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Peri-Filter System—A bulletin on the Dorrco Aldrich Peri-Filter System comprised of a Dorr-Oliver pre-treatment unit and an annular rapid sand filter combined in a single unit. Economic advantages for either municipal or industrial users are discussed.—Dorr-Oliver Inc.

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Pipe Couplings & Fittings—A 42-page general catalog including information on Dresser pipe couplings and fittings, pipe repair clamps and sleeves etc., available for the water and sewage.—Dresser Mfg. Co.

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Pipe Cutter—A catalog sheet giving details on Models 6 and 12 pipe cutters for cutting cast iron, Duriron, vitreous clay water pipe and cement sewer tile. A parts and price list is also included.—Spring Load Manufacturing Corp.

126R

Pipe Locators—A brochure describing the new automation method of etched or 'printed' circuitry now employed in the Wilkinson Line Locator. Also, included is a description of new type selective antennas and long life phenolic material used in the instrument case.—Wilkinson Products Co.

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Pipe Locator—Descriptive brochure on pipe and leak locators.—Computer Measurements Corp.

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Pipe Tools—Catalog 39 discusses pipe cutters, pipe clamps and plugs, and accessory parts.—Ellis & Ford Mfg. Co.

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Pipe Laying & Jointing Tools & Equipment—A complete general catalog showing the line of equipment for water, sewer and gas lines.—Joseph G. Pollard Co., Inc.

130R

Plastic Pipe & Fittings—A series of three bulletins giving technical data, list of resistant chemicals, etc. on Van-Cor diaphragm valves, pipe and fittings.—Colonial Plastics Mfg. Co.

Plug Valves—See Valves

131R

Pneumatic Control System—Bulletin 1100 describes the Infilco C A P system of instantaneous pneumatic control for water treatment plants.—Infilco Inc.

132R

Pneumatic Transmitter—Bulletin 285-L2A describes the BalanCel transmitter as a simple force-balance device for transmission of flow, level, and pressure data. Also for the summation, averaging, etc., of two quantities.—Builders-Providence, Inc.

133R

pH and Chlorine Control—A handbook describing the Taylor colorimetric slide comparator for pH, chlorine, phosphate, etc., as well as for water analysis. The handbook also contains valuable information on the theory and applications of colorimetric control methods.—W. A. Taylor & Co.

134R

pH Instruments—A series of three bulletins on portable pH meters and 12 bulletins on industrial pH meters provide complete information on the company's meters.—Beckman Instruments, Inc.

135R

Porous Media—Bulletin describes use of porous ceramic plates and tubes in a wide variety of equipment used in the treatment of water, sewage and industrial wastes. Charts and tables help provide data required in operating units equipped with these porous media.—The Carborundum Co.

136R

Portable Blower—Spec. Sheet gives details on the Homelite Carryable Blower that provides 1500 cfm.—Homelite Corp.

137R

Portable Generators—This bulletin contains a discussion of the many applications of a portable generator along with a list of features and construction details.—Homelite Corp.

Portable Pumps—See Pumps

138R

Pressure Pipe, Asbestos Cement—An 8-page, 2-color folder featuring Transite asbestos-cement Pressure Pipe, its manufacture, properties and advantages. The folder also shows how, in combination with the Ring-Tite coupling, makes possible installing water lines faster to last longer. Various installation photos are included.—Johns-Manville Co.

139R

Prestressed Concrete—Bulletin gives case history of how prestressing saved time and materials in the construction of the Owl's Head sewage treatment plant in New York.—Preload Co., Inc.

140R

Proportioning Pump—Bulletin 1260-2 describes on automatic and proportioning chemical feeder, the Chem-O-Feeder which utilizes water from the main itself and which will feed disinfecting solution in proportion to variable flow in the main.—Proportioneers, Inc.

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Protective Coating—A bulletin on 100 per cent inorganic zinc silicate coating that provides near-permanent protection to steel exposed to severe conditions of rust, weathering, salt air and water exposures.—Amercoat Corp.

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Protective Coating—A 32-page handbook discussing what NoDrip Plastic Coating is and what it does.—J. W. Mortell Co.

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Protective Coating—Twelve page folder containing illustrated descriptions of Bitumastic cold applied coatings, along with application data.—Koppers Co. Inc.

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Protective Coating—A bulletin on the T-Lock Amer-Plate, a continuous plastic sewer lining. "T-Lock" refers to the T shaped ribs which project from the back of the sheet, and lock the sheet into the pipe or structure when the concrete is cast.—Amercoat Corp.

145R

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Pumps, Centrifugal—A 24-page bulletin on single stage double suction centrifugal pumps.—Allis-Chalmers Mfg. Co.

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148R

Pumps, Centrifugal—Bulletin 1002 discusses single stage single and double suction centrifugal pumps with a capacity range of 50 to 600 gpm. Bulletin 1004 covers single stage double suction centrifugal pumps with capacities of 1,000 to 20,000 gpm and heads to 350 feet. Two-stage horizontal pumps with capacities of 75 to 3,000 gpm and heads to 750 feet are covered in bulletin 1501-R.—De Laval Steam Turbine Co.

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Pumps, Centrifugal—Eight page catalog on double suction, general service centrifugal pumps. It shows construction details up to 3 inch discharge size,

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and 4 to 10 inch discharge size. Design advantages, drives and typical performance curves along with installation pictures are shown.—Economy Pumps Div. of C. H. Wheeler Co.

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Pumps, Centrifugal—"Handbook for Care of Centrifugal Pumps" is an illustrated guide to proper maintenance.—Allis-Chalmers Mfg. Co.

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Pumps, Deep Well Turbine—Bulletin 245A discusses the water lubricated, Type "FA" discharge head, hollow shaft, motor drive, deep well turbine pumps. Complete specifications and a cut-away drawing explain construction features.—American Well Works.

152R

Pumps, Diaphragm Slurry—Bulletin KSP-1 describes the Komline-Sanderson 2 inch diaphragm slurry pump, a self-contained unit featuring dual ball-check valves and variable speed drive which permit gentle pumping action, positive feed and metering characteristics.—Komline-Sanderson Engineering Corp.

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Pumps, Freflo—A 12 page bulletin covering horizontal and vertical Freflo pumps for handling sewage and industrial wastes. It contains rating curves for 18 pump models. Also included are are charts for selection of shafting for use with verticle pumps. Complete dimension data are given for all pump models.—Worthington Corp.

154R

Pumps, Portable—A 12-page bulletin lists the company's line of Carryable pumps with capacities of from 5,500 gals. per hour to 15,000 gals. per hour. Installations photos and a discussion of construction features are also included.—Homelite Corp.

155R

Pumps, Sewage and Sump—Bulletin 3102 discusses the sump pump for industrial buildings, recreational parks, and pools. Bulletin 3215 covers the Drain-Dri sump pump, a heavy duty unit for handling drainage and seepage relatively free from grit. Bulletin 6251 discusses vertical sewage pumps for treatment plants, booster stations and similar industries.—Yeomans Bros. Co.

156R

Pump, Solids—A bulletin presenting the Wemco Torque-Flow Solids Pump and describing how this pump eliminates the conventional impeller. Cutaway photos and drawings show the operation of the pump. A complete dimension chart is also included.—Western Machinery Co.

157R

Pumps, Submersible—A 12-page bulletin describes the line of BJ Submersibles and lists their advantages. Safety features, special applications, specifications and selection chart are included. A list of typical municipal and industrial users are given along with a list of the sales and service offices.—Byron Jackson, Div. of Borg-Warner Corp.

158R

Pumps, Sump—A condensed bulletin featuring vertical sewage and sump pumps.—Weil Pump Co.

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Rate Controllers—Bulletins 600-G6A and 680-J94 on filter effluent or back wash rate controllers.—Builders-Providence, Inc.

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Receiver-Recorder—Specification sheets E12-5 and G91-9 covers the receiver recorder for pneumatic and electronic telemetering systems. This unit continuously records as many as four variables in any combination. Designed for plug-in receivers and controllers. Pneumatic connecting lines use ARMOR-TUBE Flexible, Protected Pneumatic Cable.—Bailey Meter Co.

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Recorders-Indicators—A handbook for engineers. Presents detailed specifications for ElectroniK non-control precision instruments.—Minneapolis-Honeywell Regulator Co.

162R

Remote Control—Bulletins on Chronoflo telemetering, "Synchro-Scan," pneumatic and electrical transmission and control of level, pressure, pumps etc. —Builders Providence, Inc.

163R

Remote Control System—A folder describing system whereby valves, pumps, etc. can be remotely or locally operated over 2 wires.—Taller & Cooper Inc.

Sewage & Sump Pumps—See Pumps

164R

Sewage and Waste Treatment—Bulletin No. 300 is a general catalog of equipment and methods for modern waste treatment—Pacific Flush Tank Co.

165R

Samplers—Bulletin 131 illustrates and discusses the Trebler samplers.—Lakeside Engineering Corp.

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Screening Equipment—Booklet 2587 illustrates and discusses Link-Belt's line of screening equipment for water, sewage and industrial waste. Dimension drawings and specifications are included. —Link-Belt Co.

167R

Sewage Ejector—Bulletins describing mechanically and electrically controlled pneumatic ejector for handling solids-bearing liquids and wastes.—Yeomans Bros. Co.

168R

Sewage Ejectors—Bulletin SE-860-C describes submersible sewage ejectors designed for handling sewage, large drainage loads, such as underpasses, sewage lift stations, etc.—Weil Pump Co.

169R

Sewage Ejector—A series of engineering tables provides a simplified method of selecting clog-proof "Flush Kleen" sewage ejectors. Examples are given for determining the inflow, discharge heads and type of ejector to use in various applications.—Chicago Pump Co.

170R

Sewage Ejector System, Pneumatic—12-page, 2 color booklet describes the Blackburn-Smith Pneumatic Sewage Ejector that can be operated by either a mechanical float and electric float switch, a mechanical float and pneumatically controlled air valves, or electrode controls. Performance charts, photographs and installation diagrams are also included.—Blackburn-Smith Mfg. Co., Inc.

171R

Sewage Lift Station—A folder describing the "Mon-O-Ject", a factory-built single pneumatic ejector sewage lift station. The unit is built for underground installation and is available in capacities of from 30 to 100 gal. per min. Smith & Loveless, Inc.

172R

Sewage Treatment—Bulletin 6041, Dorr-Oliver Equipment and Methods for Modern Sewage Treatment, describes briefly major components of Dorr-Oliver equipment available for primary through complete sewage treatment.—Dorr-Oliver Inc.

173R

Sewage Treatment—Detailed information on Pacific Flush Tank equipment available in a series of technical bulletins, fully illustrated with photographs and diagrams.—Pacific Flush Tank Co.

174R

Sewage Jointing—Three folders discuss and illustrate how unusual joint sealing problems were solved at different locations including 25-mile, 18-mile and 92-mile sewer projects.—Presstite-Keystone Engineering Products Co.

175R

Sewer Pipe, Asbestos Cement—An 8-page, 2-color folder featuring Transite asbestos-cement sewer pipe, lists its advantages, and how it, with the Ring-Tite coupling makes possible tight sewer systems at low installation cost.—Johns-Manville Co.

176R

Sewer Pipe, Clay—Catalog SE-50 gives a complete summary of shapes and sizes of clay sewer pipe and supplementary clay products.—Natco Corp.

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177R

Sewer Sealing System—"3 Steps to Tighter Sewer Joints" is a 20-page booklet on the Presstite Sealing System. The three steps, specifications, and actual installation photographs are also included. Presstite-Keystone Engineering Products Co.

178R

Silica (Activated) Feeder—Catalog 60.110 gives description, design features, operating instructions and technical information on the series A-637 WT Silactor, a device for the continuous production and application of chlorine activated silica.—Wallace & Tiernan, Inc.

179R

Silica Activator and Feeder—Bulletin 63-M1 describes equipment designed for the continuous activation and feeding of sodium silicate. The unit features sequence starting, automatic rinse, anti-gel interlock and variation of aging concentration and aging time.—Omega Machine Co.

180R

Silicate, Sodium—A bulletin describing how silicate of soda serves industry and gives a comprehensive listing of products made by the company with a description of their uses.—Philadelphia Quartz Co.

181R

Slide Gates—Discusses gates and guides of acid and alkaline resistant Chemstone. Guides may be set in place before pouring concrete.—Filtration Equip. Corp.

182R

Sludge Digesters—Bulletin 135 gives complete information on the Spiragesters. Lakeside Engineering Corp.

183R

Sludge Digestion—Bulletin 6262 describes the Dorrco Densludge Process consisting of a grit washer, thickener, digester and spiral heat exchanger.—Dorr-Oliver Inc.

184R

Sludge Digestion—Bulletin 6591 presents the Dorr type MA digester which incorporates, single stage digestion, high capacity mixing and gas storage in a single unit.—Dorr-Oliver Inc.

185R

Sludge Digestion—Specific bulletins are available on controlled sludge digestion, heat exchangers, garbage digestion, etc.—Pacific Flush Tank Co.

186R

Sludge Digestion Tanks—Bulletin on use of prestressed concrete in the construction of sludge digestion tanks.—Preload Co., Inc.

187R

Sludge Drying and Incineration—Bulletin FD-52 covers the C-E Raymond System of Sludge Drying and Incineration. It briefly outlines the problem of sewage disposal and shows why heat drying and incineration are regarded as an ideal solution. Diagrams and photographs are also included.—Combustion Engineering Inc.

188R

Sludge Removal—Bulletin 253B details the American conveyor, American circular clarifier, and the American sludge control valve used in sludge removal. Diagrams and installation photos are included.—American Well Works.

189R

Sludge Remover—Bulletin 315-81 covers the low cost Rex Unitube Tow-Bro sludge remover. Photographs and diagrams of the unit are also included.—Chain Belt Co.

190R

Softener and Clarifier—The Reactivator, a high rate cold process softener and clarifier. Cut-away "how-it-works," drawing is also included.—Graver Water Conditioning Co.

Standpipes—See Elevated Storage

191R

Steel Pipe—Booklet 402 describes the construction of a 72-inch Ramapo force main for the North Jersey Water Commission. Booklet 408 covers the construction of a 37,000-ft. Northwest pumping main at Reading Pa. The Welded Steel Pipe booklet describes the fabrication of a 96-inch steel pipe and its installation at Sparrows Point, Md.—Bethlehem Steel Co.

Submersible Pumps—See Pumps

192R

Supervisory Control—Bulletin 240-M6 describes unlimited number of control or advisory functions from central control panel over widely spread system using sequencing transmission system.—Builders-Providence, Inc.

193R

Supervisory Control—Bulletin AA-2 describes some of the applications of supervisory control for plant operations, provides illustrations of the various equipment used and gives a brief description of the method of operation for this automatic and remote control unit.—Control Corp.

194R

Surge and Water Hammer Control—A bulletin on the Controlled Closing Air Valve designed for the protection of pipe lines against surge built-up pressures or water hammer.—Simplex Valve & Meter Co.

195R

Steam Cleaner—Booklet discusses the Hypressure Jenny steam cleaner for cleaning and deodorizing bar screens, grit and scum loading pits, etc.—Homestead Valve Mfg. Co.

196R

Tapping Machines—Bulletin T-54 discusses the Smith tapping machine for tapping operations 2 to 12 inches. Features of power and hand operated machines, accessories and operating instructions are also included.—A. P. Mfg. Co.

197R

Tapping Sleeves and Valves—A circular on tapping sleeves and valves.—M & H Valve and Fittings Co.

198R

Telemetering—A bulletin describing the TM-15 high speed telemetering system and the principle of its operation and possible applications. Illustrations are included.—Control Corp.

199R

Telemetering—Bulletins on tone signaling equipment and remote control equipment for plant operations.—Hammarlund Mfg. Co., Inc.

200R

Taste and Odor Control—This booklet describes the use of Aqua Nuchar activated carbon in water purification.—West Virginia Pulp & Paper Co.

201R

Tenon Tool—A catalog sheet with information on the Spring Load tenon tool. This tool will machine pipe ends for: Ring-Tite couplings; Simplex couplings; Roto-Split flanges; poured flange assembly; tapered couplings; making closures; and end facing.—Spring Load Manufacturing Corp.

202R

Trash Racks—Bulletin No. 158 describes the Leonard Trash Rack Rakes with dimensions, specifications, and typical arrangements.—S. Morgan Smith Co.

203R

Trenchers and Backfillers—A 2-color booklet describing the features and listing specifications of the models 92 and 95 "Baby Diggers," the models 110, 140, 240, and 320 standard trenchers, and models 80W and 190 backfillers. Photographs of each piece of equipment are shown along with illustrations of the equipment in operation.—Cleveland Trencher Co.

204R

Trenching & Construction Equipment—Thirteen bulletins on tractors, crawlers, trenchers and loaders for installation of water mains or sewers.—Oliver Corp.

Use Accompanying Reply Card to Obtain Copies of these Bulletins.

205R
Trickling Filter Distributor—This bulletin describes the Dorrco Distrbutor, a self-propelled rotary unit for low and high rate trickling filters.—Dorr-Oliver Inc.

206R
Trickling Filters Distributor—Bulletin 313A covers spreader jets for rotary distributors for trickling filters.—Pacific Flush Tank Co.

207R
Upflow Clarifier—Bulletin 6W46 describes clariflow unit, a vertical rise clarification unit for circular, square and rectangular tanks.—Walker Process Equip. Inc.

208R
Upflow Coagulation—Twenty-eight page, 4-color bulletin describes the development, operating features and distinguishing characteristics of the "Accelator" unit.—Infilco Inc.

209R
Upflow Coagulation Unit—A 20-page bulletin describes the operation, advantages, and design features of the Permutit Precipitator and contains flow diagrams, installation photos and specifications.—Permutit Co.

210R
Vacuum Filter—Latest information on the Coilfilter, a vacuum filter which features non-clogging permanent filter media to obtain constant output, low operating cost, and simplified operation. Standard sizes of equipment are listed. —Komline-Sanderson Engineering Corp.

211R
Valve and Meter Boxes—Bulletin 2000 on Valve, Roadway, Service and Meter Boxes along with Manhole Frames and Covers.—Alabama Pipe Co.

212R
Valve Controls and Gear Drives—A folder illustrating and discussing various gear motors and controls, including the LimiTorque valve controls. Catalogs numbers are given for complete information about each product.—Philadelphia Gear Works, Inc.

213R
Valves —A folder discussing bronze and iron valves, gate, globe, angle, check and meter valves, sluice gates, pivot valves and motor unit.—Chapman Valve Manufacturing Co.

214R
Valves—Catalog 254 covers valves for water works and sewage service.—Eddy Valve Co.

215R
Valves, Air—A catalog giving complete information on the Crispin Air Valve. Multiplex Manufacturing Co.

216R
Valves, Altitude and Level—Bulletin W-4-A describes altitude valves and modifications of water level control valves.—Golden-Anderson Valve Specialty Co.

217R
Valves and Hydrants—Circular 49 is a listing of a complete line of gate valves and hydrants with mechanical joint ends.—M & H Valve and Fittings Co.

218R
Valves and Hydrants with Ring Tite Joint—A discussion of Smith gate valves and fire hydrants now available with Ring-Tite coupling joint for Transite pressure pipe. The back page lists the company's line of products for water works, gas and oil industries.—A. P. Smith Mfg. Co.

219R
Valves, Butterfly—A manual on rubber seated butterfly valves containing complete information including data on valve sizing, operator selection, theory of valve design, etc.—Henry Pratt Co. Inc.

220R
Valves, Butterfly—Bulletin 650-L1B on tight-closing rubber seated butterfly valves built to AWWA specifications.—Builders-Providence, Inc.

221R
Valves, Butterfly—specifications of Continental butterfly valves positioned by Honeywell diaphragm motors for precise control of water, sewage, sludge and other fluid flow rates.—Minneapolis-Honeywell Regulator Co.

222R
Valves, Check—Bulletin #W-1 illustrates and describes cushioned type swing check valves.—Golden-Anderson Valve Specialty Co.

223R
Valves Cone—A 32-page bulletin describing Rotovalves, with complete dimensions, arrangements and various applications.—S. Morgan Smith Co.

224R
Valves, Diaphragm—Folder gives complete information on the Grinnell-Saunders strightway diaphragm valve.—Grinnell Co. Inc.

225R
Valves, Gate—A 38 page bulletin listing the complete line of double disc parallel seat water works gate valves. Plant facilities and details on each valve are illustrated and discussed.—Ludlow Valve Manufacturing Co., Inc.

226R
Valves, Gate—Bulletin A describes the complete line of gate valves manufactured by the company.—Rensselaer Valve Co., Div.

227R
Valves, Plug—Book 39-2 describes cam-sealed quarter-turn plug valves. Book 39-3 shows lever-sealed quarter-turn plug valves with built-in means of moving plug under all conditions. Book 39-5 describes lubricated plug valves in strailghtway, 3-way, 4-way and multiple port types.—Homestead Valve Mfg Co.

228R
Valves, Plug—Catalog on valves for water, sludge gas service; valve accessories and lubricants.—Rockwell Mfg. Co.

229R
Valves, Plug—This 18-page manual discusses the various lubricants for ACF plug valves. Amply illustrated with photographs and tables the manual gives descriptions of the lubricants, service recommendations and ordering instructions for the lubricants.—ACF Industries, Inc.

230R
Water and Waste-Water Equipment—Catalog 833 gives the complete line of Jeffrey equipment for the treatment of water, sewage and industrial waste. Included are grit and sludge collectors, bar and water screens, flocculation equipment, scum removers, etc.—Jeffrey Manufacturing Co.

231R
Water and Waste-Water Treatment—Bulletin 35-D illustrates and describes equipment used for treatment of water, sewage and trade wastes.—Hardinge Co.

232R
Water Screens, Travelling—A 4-page bulletin containing data on travelling water screens for positive removal of floating debris, and suspended matter from water treatment plant influent.—Jeffrey Manufacturing Co.

233R
Water Treatment—A general folder lists the various bulletins, pertaining to water treatment.—General Filter Co.

234R
Well Screens—Series of bulletins presents the construction, development and operation of wells—Edward E. Johnson, Inc.

235R
Well Strainers—A new 48-page catalog describes the self cleaning V-shaped slot well strainers, and contains information concerning the recommended procedure for well strainer installation, uses, etc.—Cook Well Strainer Co.

236R
Well Water Systems—Bulletin 100 illustrates and discusses pumps, drilling, allied services and equipment available from the company.—Layne & Bowler, Inc.

237R
Wrought Iron Pipe—A catalog listing current literature on wrought iron pipe and plates.—A. M. Byers Co.

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